

Iowa Water Center Annual Technical Report FY 2014

Introduction

The Iowa Water Center (IWC) may be a small Water Resources Research Institute in size, but its impact is felt throughout the state and the country. Iowa Water Center Director Rick Cruse completed his 9th year as director in 2015 and Program Coordinator Melissa Miller continued into a third year during this reporting period. Continuity of staff allowed the Center to develop stability and growth in all aspects of program management and set the stage for future transformational growth activities.

Research Program Introduction

The Iowa Water Center (IWC) represents a model of Water Resources Research Institutes that relies heavily on its 104(b) funding to carry out its charge of research, outreach and education related to Iowa's water. In FY2014, IWC was able to leverage those funds with a \$25,000 commitment to the seed grant fund from the Leopold Center for Sustainable Agriculture. This expanded our research program to three projects for FY2014, including a project that was selected for funding in FY2013, but cut due to sequestration.

The FY2014 call for proposals did not undergo significant changes from FY2013; the research focus remained on climate change. The three projects chosen were: Development of a Framework for Discharge Forecasting over Iowa; Cost-Effectiveness of Reverse Auctions for Watershed Nutrient Reductions in the Presence of Climate Variability; and Validation of Satellite Observations of Soil Moisture to Facilitate Forecasts of Soil Water Storage in Iowa.

IWC also submitted two proposals to the 104(g) program: Predicting the quantity and quality of water from collector wells during hydrologic extremes; and Development of a Comprehensive Hazard to Loss Modeling Methodology for the Residential Damage Associated with Inland Flooding from North Atlantic Tropical Cyclones. The latter project was selected for funding.

Finally, IWC facilitated the transfer of a previously funded 104(g) project when the PI took a job at another institution. This project, Watershed scale water cycle dynamics in intensively managed landscapes: bridging the knowledge gap to support climate mitigation policies, is now being conducted from the University of Tennessee, Knoxville, and has been extended due to an extensive delay in administering the transfer.

Watershed scale water cycle dynamics in intensively managed landscapes: bridging the knowledge gap to support climate mitigation policies

Basic Information

Title:	Watershed scale water cycle dynamics in intensively managed landscapes: bridging the knowledge gap to support climate mitigation policies
Project Number:	2012IA215G
USGS Grant Number:	G12AP20154
Start Date:	9/1/2012
End Date:	8/31/2014
Funding Source:	104G
Congressional District:	IA-2nd
Research Category:	Climate and Hydrologic Processes
Focus Category:	Agriculture, Hydrology, Water Quantity
Descriptors:	None
Principal Investigators:	Thanos N Papanicolaou, Keith Edwin Schilling, Douglas James Schnoebelen, Christopher Wilson

Publications

1. Dermisis, D., A.N. Papanicolaou, B. Abban, and D. Flanagan. Dynamic approach for predicting soil transport and delivery from fields and small catchments to headwater streams: field experiments and analysis. *Earth Surface Processes and Landforms*. In Preparation (2014).
2. Papanicolaou, A.N., M. Elhakeem, C.G. Wilson, C.L. Burras, L.T. West, B. Clark, and B. Oneal. Understanding the variability of saturated hydraulic conductivity at the hillslope scale due to soil property heterogeneity induced by land management and erosion. *Hydrological Sciences Journal*. In Preparation (2014).
3. Dermisis, D., A.N. Papanicolaou, B. Abban, and D. Flanagan. Dynamic approach for predicting soil transport and delivery from fields and small catchments to headwater streams: field experiments and analysis. *Earth Surface Processes and Landforms*. In Preparation (2014).
4. Papanicolaou, A.N., M. Elhakeem, C.G. Wilson, C.L. Burras, L.T. West, B. Clark, and B. Oneal. Understanding the variability of saturated hydraulic conductivity at the hillslope scale due to soil property heterogeneity induced by land management and erosion. *Hydrological Sciences Journal*. In Preparation (2014).
5. Papanicolaou, A.N., M. Elhakeem, C.G. Wilson, C.L. Burras, L.T. West, B. Clark, and B. Oneal. 2015. Spatial variability of saturated hydraulic conductivity at the hillslope scale: Understanding the role of land management and erosional effect. *Geoderma*. 243-244:58-68.
6. Schilling, K.E., M.T. Streeter, K.J. Hutchinson, C.G. Wilson, B. Abban, K.M. Wacha, and A.N. Papanicolaou. 2015. Evaluating the effects of land cover on streamflow variability in a small Iowa watershed: Toward development of sustainable and resilient landscapes. Submitted to *American Journal of Environmental Science*
7. Abban, B., A.N. Papanicolaou, M.K. Cowles, C.G. Wilson, O. Abaci, K. Wacha, and K.E. Schilling. Sediment source dynamics in the headwater stream of an intensively cultivated agricultural

- watershed: A Bayesian fingerprinting study using stable isotopes. *Water Resources Research*. In Preparation (2015).
8. Dermisis, D., A.N. Papanicolaou, B. Abban, and D. Flanagan. Dynamic approach for predicting soil transport and delivery from fields and small catchments to headwater streams: field experiments and analysis. *Earth Surface Processes and Landforms*. In Preparation (2015).
 9. Papanicolaou, A.N., M. Elhakeem, D. Chang, C.G. Wilson, K. Schilling, D. Schnoebelen: From hydroscape to soilscape- A remote sensing approach to quantify flow paths and ponding regions In Iowa. *CATENA*, In Preparation (2015).

NIWR ANNUAL SUMMARY

Title: Watershed scale water cycle dynamics in intensively managed landscapes: Bridging the knowledge gap to support climate mitigation policies.

Sponsor Award/Grant #: G12AP20154

Annual Summary: March 1, 2014 to February 28, 2015

PI: A.N. Papanicolaou,
Professor and Henry
Goodrich Chair of Civil
and Environmental
Engineering, The
University of Tennessee

1) Problem/Research Objectives

Our **overarching goal** for this project is to develop an integrative suite of established models to account better for the interplay between Land Use/ Land Cover (LU/LC) and climate on the water cycle dynamics in rapidly changing Midwestern landscapes at the watershed scale. In this reporting period, we have used a Top-Down Approach with the Soil and Water Assessment Tool (or SWAT model) to identify critical sub-watersheds in terms of their contributions to flooding within the Clear Creek, IA watershed (Figure 1). We are currently using a Bottom-Up Approach with the Water Erosion Prediction Project (or WEPP model) to

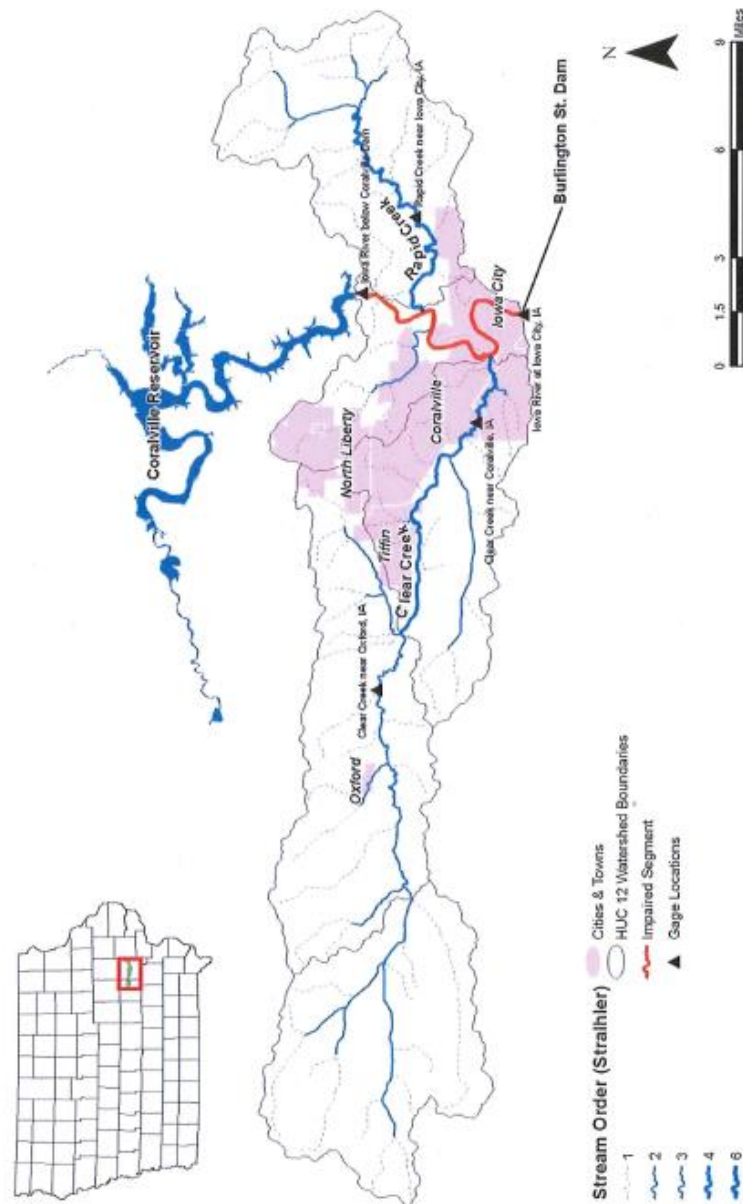


Figure 1: Clear Creek watershed

assess specific Best Management Practices (BMPs) within these critical sub-watersheds and to quantify accurately the partitioning of surface and subsurface flow for assessing BMP efficiency.

2) Methodology

For the Top-Down Approach, a total of 20 subbasins and 1,786 hydrologic response units (HRUs) in the Clear Creek watershed were simulated using SWAT to determine daily hydrologic parameters that were for input into the Indicators of Hydrologic Alteration (IHA) program. The total simulation period was 13 years (2000-2012) and calibration of the model was achieved by adjusting several hydrologic parameters, including the curve number, soil available water capacity, evaporation compensation coefficient, and groundwater delay within their acceptable ranges. Model calibration was evaluated using the coefficient of determination and the Nash-Sutcliffe coefficient.

The IHA software program (Richter et al., 1996) was used to analyze observed daily streamflows from the two USGS gages in Clear Creek and the SWAT-simulated subbasin streamflows to characterize hydrologic variability resulting from different land covers. The IHA program uses 33 hydrologic attributes (e.g., magnitude, duration, timing and frequency of extreme events) to statistically characterize hydrologic variation, which in turn generates indicator statistics.

For the Bottom-Up Approach, WEPP simulations were used to help determine the efficiencies of BMPs, such as grassed waterways and Alternative Tiles Intakes (i.e., modified rock filters with wood chips to facilitate denitrification) placed in Clear Creek. The model simulations utilized previously measured single rainfall events and design storms to determine the production of water and sediment to the BMPs. The WEPP event simulations were conducted for six measured rainfall events, along with design storms ranging from the 2-yr, 24-hr event to the 100-yr, 24-hr event, using variable initial conditions to capture a full distribution of possible results.

3) Principal Findings and Significance

In this study, we evaluated how different dominant land covers affect key hydrologic indicators within Clear Creek subbasins and identify future vulnerabilities to stream health and infrastructure as the LU/LC and climate change. In summary, subbasins dominated by urban land cover had lower minimum streamflows and showed evidence for greater flashiness as seen with a greater frequency of reversals, shorter duration of events and faster rise and fall rates, all which can be attributed to a greater proportion of impervious surfaces have less groundwater recharge and provide less sustainable baseflow to streams. Subbasins dominated by row crop land cover had greater water yield and maximum flows and higher peak flows, in parts due to the higher curve numbers for agricultural areas and the compaction from the intense farm activities (Papanicolaou et al., 2015). Greater water yield from row crop areas is consistent with patterns of increasing streamflow trends observed in watersheds with increasing amounts of row crop land cover (Tomer et al., 2005; Zhang and Schilling, 2006). Given the preponderance of row crop land cover in the Clear Creek watershed (62%), we suspect that the greater frequency and longer duration of high flows at the watershed outlet is due to the influence of row crop areas on

watershed-scale hydrology. Schilling et al. (2013) reported that conversion of land use from row crops to switch grass or extended sod-based crop rotations in a highly agricultural Iowa watershed would reduce downstream flood frequency and severity. Grass-dominated subbasins had lower rise and fall rates, fewer zero days and fewer reversals than subbasins under urban or row crop land cover. Grasslands are known to increase infiltration and reduce flooding potential (Schilling and Drobney, 2014). Ecosystems dominated by grasslands rapidly infiltrate water, slowing runoff and lessening the kinetic energy of falling raindrops (Knox, 2001).

Additionally considered for the different subbasins were changes in land management (e.g., conversion to grasslands, change in tillage regime), supplemented with the results from the WEPP model simulations. Simulating a LULC conversion was done through altering curve number values. Grassed areas tend to have lower runoff volumes and rates than agricultural fields; therefore, increasing the acreage of grassed areas, whether it will be through the addition of grassed waterways to a field or converting whole fields to CRP, would reduce flood volumes (e.g., Dermisis et al., 2010). Conservation tillage increases the level of residue left on a field after harvest. The added residue has an effect on the CN, lowering it substantially (Elhakeem and Papanicolaou, 2012). For the most part, though, the runoff reduction potentials of both the conversion to grassland and to no-till are small and thus a high level of land use conversion is needed to produce significant reductions. For example, average reductions in runoff volumes and peak flows of 16% were observed in all sub-watersheds for a 50% conversion. Thus, multiple practices must be incorporated to produce significant effects.

Dermisis, D., O. Abaci, A.N. Papanicolaou, and C.G. Wilson. 2010. Evaluating grassed waterway efficiency in southeastern Iowa using WEPP. *Soil Use and Management*. 25(2):183-192.

Elhakeem, M., and A.N. Papanicolaou. 2012. Runoff Curve Number and Saturated Hydraulic Conductivity Estimation via Direct Rainfall Simulator Measurements. In: James, Irvine, Li, Pitt, and Wright (Eds). *On Modeling Urban Water Systems*. Monograph 20. CHI Press, 2012.

Knox, J.C. 2001. Agricultural influence on landscape sensitivity in the Upper Mississippi River Valley. *Catena*. 42:193-224.

Papanicolaou, A.N., M. Elhakeem, C.G. Wilson, C.L. Burras, L.T. West, H. Lin, B. Clark, and B.E. Oneal. 2015. Spatial variability of saturated hydraulic conductivity at the hillslope scale: Understanding the role of land management and erosional effect. *Geoderma*. 243–244:58–68.

Richter, B.D., Baumgartner, J.V., Powell, J., Braun, D.P., 1996. A method for assessing hydrologic alteration within ecosystems. *Conservation Biology*. 10:1163-1174.

Schilling, K.E., and P. Drobney. 2014. Restoration of Prairie Hydrology at the Watershed Scale: Two Decades of Progress at Neal Smith National Wildlife Refuge, Iowa. *Land*. 3:206-238.

Schilling, K.E., P.W. Gassman, C.L. Kling, T. Campbell, M.K. Jha, C.F. Wolter, and J.G. Arnold. 2013. The potential for agricultural land use change to reduce flood risk in a large watershed. *Hydrological Processes*. 28:3314-3325.

Tomer, M., D. Meek, and L. Kramer. 2005. Agricultural practices influence flow regimes of headwater streams in western Iowa. *Journal of Environmental Quality*. 34:1547-1558.

Zhang, Y.-K., and K. Schilling. 2006. Increasing streamflow and baseflow in Mississippi River since the 1940s: Effect of land use change. *Journal of Hydrology*. 324:412-422.

4) *Summary and Conclusions*

Progress during this year was limited due to the transfer of the PI and one of the co-PIs from the University of Iowa to the University of Tennessee. The process for transferring the award to the University of Tennessee was begun in August 2013, before the PI left the University of Iowa. The grant has been frozen for this transfer since August of 2013. The logistics of transferring the contract to the new university were not resolved until nearly six months after PI Papanicolaou began at UTK (June 2014). This severely delayed the project. Delays were experienced while deciding whether or not the award would be terminated from the Iowa Water Center and transferred to the Tennessee Water Center. Additionally, there were re-budgeting discussions for meeting the cost-share requirements during the new sub-contract negotiations.

5) *Listing of publications that have resulted from this research*

Papanicolaou, A.N., M. Elhakeem, C.G. Wilson, C.L. Burras, L.T. West, B. Clark, and B. Oneal. 2015. Spatial variability of saturated hydraulic conductivity at the hillslope scale: Understanding the role of land management and erosional effect. *Geoderma*. 243-244:58-68.

Schilling, K.E., M.T. Streeter, K.J. Hutchinson, C.G. Wilson, B. Abban, K.M. Wacha, and A.N. Papanicolaou. 2015. Evaluating the effects of land cover on streamflow variability in a small Iowa watershed: Toward development of sustainable and resilient landscapes. Submitted to *American Journal of Environmental Science*

Abban, B., A.N. Papanicolaou, M.K. Cowles, C.G. Wilson, O. Abaci, K. Wacha, and K.E. Schilling. Sediment source dynamics in the headwater stream of an intensively cultivated agricultural watershed: A Bayesian fingerprinting study using stable isotopes. *Water Resources Research*. In Preparation (2015).

Dermisis, D., A.N. Papanicolaou, B. Abban, and D. Flanagan. Dynamic approach for predicting soil transport and delivery from fields and small catchments to headwater streams: field experiments and analysis. *Earth Surface Processes and Landforms*. In Preparation (2015).

Papanicolaou, A.N., M. Elhakeem, D. Chang, C.G. Wilson, K. Schilling, D. Schnoebelen: From hydroscape to soilscape- A remote sensing approach to quantify flow paths and ponding regions In Iowa. CATENA, In Preparation (2015).

6) *Student support provided by this research*

The following students received at least partial support (both funded and unfunded) from this project: Ben Abban, Will Ettema.

7) *Achievements and awards for this research*

n/a

8) *Any additional funding this research has received*

The information gathered from this project was used to develop the following proposals:

Item	Title	Funding Agency	Start date	Budget	Role	Status
1	CNH-L: Adopt to sustain: The effect of biophysical and socioeconomic context on the ability of two contrasting US agroecosystems to respond to changes	National Science Foundation – Dynamics of Coupled Natural Human Systems	8/1/2015 – 7/31/2020	\$1,800,000	PI	pending
2	A Statewide Water Resources Assessment for Tennessee	State of Tennessee – Water Resources Technical Advisor Committee	TBD	TBD	Co-PI	pending
3	Using Hydro-Economic Modeling to Optimally Allocate Water in the Humid Southeastern U.S.	U.S. Department of Agriculture – National Institute for Food and Agriculture	9/30/2014 – 9/29/2017	\$205,008	Co-PI	accepted
4	Increasing the Resilience of Agricultural Production in the Tennessee River Basin through More Efficient and Less Impactful Use of Water Resources	U.S. Department of Agriculture – Agriculture and Food Research Initiative	4/1/2015 – 3/31/2020	\$935,782	Co-PI	accepted
5	The role of soil heterogeneity and vegetation cover on evapotranspiration under different land-uses in Tennessee	U.S. Geological Survey – National Institute for Water Resources (104B)	4/1/2015 – 3/31/2016	\$15,000	PI	accepted
6	The coupling of Bottom-Up Evapotranspiration Approaches with Remote Sensing Measurements to close the water budget in adjoining urban and	U.S. Geological Survey – National Institute for Water Resources (104G)	10/1/2015 – 9/31/2018	\$206,914	PI	pending

	agricultural areas in the U.S. Southeast					
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Validation of Satellite Observations of Soil Moisture to Facilitate Forecasts of Soil Water Storage in Iowa

Basic Information

Title:	Validation of Satellite Observations of Soil Moisture to Facilitate Forecasts of Soil Water Storage in Iowa
Project Number:	2014IA252B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	IA - 004
Research Category:	Climate and Hydrologic Processes
Focus Category:	Agriculture, Drought, Water Quantity
Descriptors:	None
Principal Investigators:	Brian Hornbuckle

Publications

1. Hornbuckle, B. K., New Satellites for Soil Moisture: Good for Iowans! Getting Into Soil and Water: 2014, p20-22, D.C. McDonough, Ed., Iowa Water Center, Ames, IA, 2014.
2. Rondinelli, W.J., B. K. Hornbuckle, J. C. Patton, M.H. Cosh, V.A. Walker, B.D. Carr, and S.D. Logsdon, Different Rates of Soil Drying After Rainfall are Observed by the SMOS Satellite and the South Fork In Situ Soil Moisture Network, Journal of Hydrometeorology, doi: 10.1175/JHM-D-14-0137.1, 2015.

Validation of Satellite Observations of Soil Moisture to Facilitate Forecasts of Soil Water Storage in Iowa *

Brian K. Hornbuckle, Associate Professor
Department of Agronomy
Iowa State University of Science and Technology
bkh@iastate.edu 515-294-9868

Focus Categories: Agriculture (AG);
Drought (DROU); Water Quantity (WQN).

Research Category: Hydrology (HYDROL).

Keywords: soil moisture; satellite remote sensing; weather forecasting;
climate prediction; agriculture.

Duration of Project: 2 years, June 1, 2014, to May 31, 2016.

Congressional District: Iowa District 4

May 8, 2015

*Progress report for the period 3/1/14 - 2/28/15.



Figure 1: At left, the European Space Agency’s Soil Moisture and Ocean Salinity (SMOS) satellite. At right, NASA’s Soil Moisture Active Passive (SMAP) satellite.

1 Problem and Research Objectives

Soil moisture is the reservoir of water that supports agriculture and consequently much of the human race. Soil moisture also affects the amount and variability of precipitation and hence the occurrence of flooding and drought.

Remote sensing satellites that observe near-surface soil moisture have recently been deployed (Figure 1). The European Space Agency’s Soil Moisture and Ocean Salinity (SMOS) satellite mission was launched in late 2009, and NASA’s Soil Moisture Active Passive (SMAP) satellite mission was launched in early 2015.

Before measurements of near-surface soil moisture made from space can be used to estimate the amount of water stored in the soil and improve weather and climate predictions, the quantitative value of the measurements must be known. In other words, the satellite observations must be compared to a standard or what is considered the “truth” through a process known as validation.

Our research objectives for this project are as follows.

- Validate and then, if necessary, improve SMOS observations of near-surface soil moisture in Iowa.
- Initiate the validation of SMAP observations of near-surface soil moisture observations in Iowa.

2 Methodology

We will use a network of in situ soil moisture measurements located in the watershed of the South Fork Iowa River as the validation standard for both SMOS and SMAP. The network consists of 20 nodes. At each node soil moisture is measured in situ with buried instruments that relate the electrical properties of the soil to volumetric water content. Other relevant measurements such as soil temperature and precipitation are also made at each node.

Along with the permanent measurements of soil moisture, periodic measurements with hand-held devices are made to calibrate the buried instruments to the soil type of the area

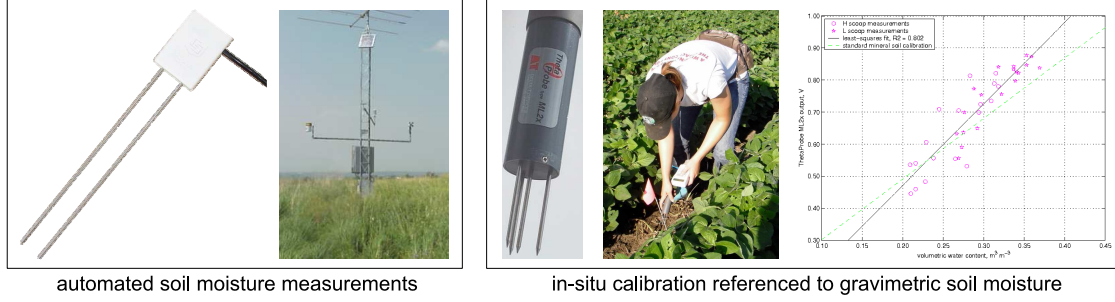


Figure 2: At left, in-situ automated soil moisture sensors. At right calibration of a Theta Probe to a gravimetric reference.

and to scale them to better represent the soil moisture conditions of a larger area. Pictures of these instruments are shown in Figure 2.

Both the SMOS and SMAP missions are striving to meet the same precision metric, which is a root-mean-square-error (RMSE) of less than $0.04 \text{ m}^3 \text{ m}^{-3}$ in observations of near-surface volumetric soil moisture.

3 Principle Findings and Significance

We have found that SMOS soil moisture observations are noisy and have a dry bias as compared to the South Fork network. See Figure 3. The RMSE of the satellite observations is about $0.06 \text{ m}^3 \text{ m}^{-3}$ ($0.05 \text{ m}^3 \text{ m}^{-3}$ in 2013 and $0.07 \text{ m}^3 \text{ m}^{-3}$ in 2014) which is larger than the mission goal. Average bias (South Fork minus SMOS) is $0.06 \text{ m}^3 \text{ m}^{-3}$ ($0.06 \text{ m}^3 \text{ m}^{-3}$ in 2013 and also $0.06 \text{ m}^3 \text{ m}^{-3}$ in 2014).

We are testing several hypotheses that could explain why SMOS is noisy and “dry” as compared to the South Fork network.

1. Incorrect surface temperature used in the soil moisture retrieval model.
2. Radio-frequency interference (RFI) from anthropogenic sources emitting radiation in the band of wavelengths measured by SMOS.
3. Land cover in the SMOS global database does not match what is on the ground in the South Fork. Vegetation is the single most important factor that must be taken into account in order to retrieve soil moisture.
4. Soil texture in the SMOS global database that does not match the actual soil characteristics in the South Fork. After soil moisture, vegetation, and surface temperature, soil texture has the largest impact on SMOS measurements.

Once we determine the problem, we will attempt to implement an improved soil moisture retrieval algorithm.

We have tested the first hypothesis. In order to retrieve soil moisture from SMOS measurements, the temperature of the soil and vegetation must be known to within a certain degree of accuracy. SMOS gets this estimate of surface temperature, T_{gc} , from the European

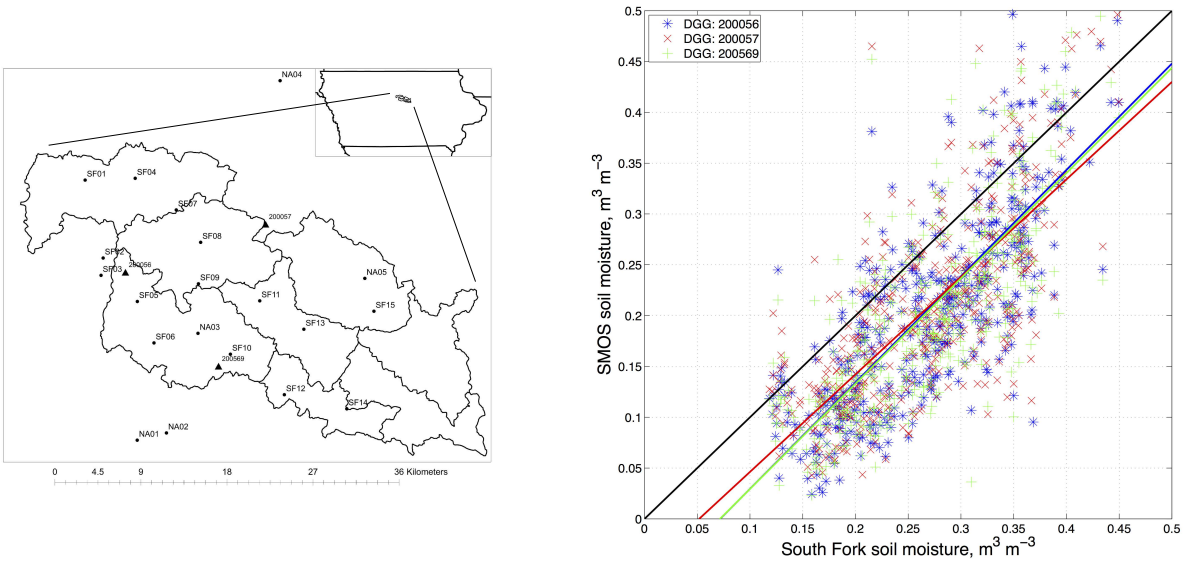


Figure 3: At left, the locations of the 20 nodes of a network of in-situ automated soil moisture sensors in the watershed of the South Fork Iowa River. At right, a comparison of SMOS soil moisture observations from the three closest SMOS pixels (DGGs 200056, 200057, 200569) and the average network soil moisture.

Centre for Medium Range Weather Forecasting (ECMWF). If ECMWF surface temperature is too cold, then the SMOS retrieval algorithm would make the soil drier in order to match observations.

We have compared T_{gc} from the ECMWF with T_{gc} that we have calculated using soil temperatures measured by the South Fork network and 2-m air temperature from the Iowa Environmental Mesonet. The comparison for the months of May through October for years 2013 and 2014 is shown in Figure 4. The average bias (SMOS minus South Fork) is 0.6 K (1.0 K in 2013 and 0.2 K in 2014) and the average RMSE is 1.8 K (2.0 K in 2013 and 1.5 K in 2014). The data indicate that SMOS surface temperature from the ECMWF is *higher* than our in situ surface temperature. This is opposite of what would explain the SMOS dry bias.

We have begun to test the second hypothesis. We have compared morning (6 am) and evening (6 pm) SMOS observations separately with the South Fork network. If RFI is present, then there should be a significant difference in the statistics of morning and evening observations since SMOS is “looking” at Earth’s surface at a different orientation relative to the surface. Any anthropogenic sources of radiation will, by definition, have a specific directional nature. Our preliminary analysis suggests that RFI is not present.

4 Notable Achievements or Awards

None.

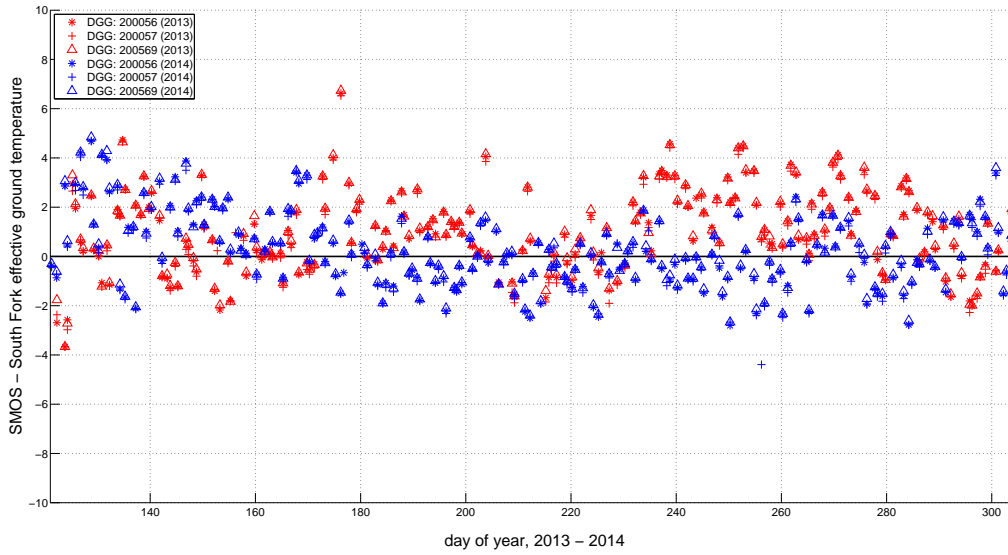


Figure 4: A comparison of the effective surface temperature T_{gc} from the in situ South Fork network and the temperature used to retrieve soil moisture from SMOS for the three closest SMOS pixels (DGGs 200056, 200057, and 200569), for May through October of the years 2013 and 2014.

5 Student Support

The funding for this project is supporting the work of Victoria Walker, a graduate student at Iowa State University working towards the master of science degree in agricultural meteorology. Erik Endacott, a first-year undergraduate student in the honors program at Iowa State, has also begun to work on the project and is earning academic credit.

6 Publications

1. Hornbuckle, B. K., New Satellites for Soil Moisture: Good for Iowans! *Getting Into Soil and Water: 2014*, p20-22, D. C. McDonough, Ed., Iowa Water Center, Ames, IA, 2014.
2. Rondinelli, W. J., B. K. Hornbuckle, J. C. Patton, M. H. Cosh, V. A. Walker, B. D. Carr, and S. D. Logsdon, Different Rates of Soil Drying After Rainfall are Observed by the SMOS Satellite and the South Fork In Situ Soil Moisture Network, *Journal of Hydrometeorology*, doi:10.1175/JHM-D-14-0137.1, 2015.

Development of a Framework for Discharge Forecasting over Iowa

Basic Information

Title:	Development of a Framework for Discharge Forecasting over Iowa
Project Number:	2014IA253B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	IA-002
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Hydrology, Floods
Descriptors:	None
Principal Investigators:	Gabriele Villarini, Aaron M. Strong

Publications

1. Karlovits, G.S., G. Villarini, A.A. Bradley, and G.A. Vecchi, Diagnostic evaluation of NMME precipitation and temperature forecasts for the continental United States, 95th American Meteorological Society Annual Meeting, Phoenix, Arizona, January 4-8, 2015.
2. Karlovits, G.S., G. Villarini, A. Bradley, and G.A. Vecchi, Diagnostic evaluation of NMME precipitation and temperature forecasts for the continental United States, AGU Fall Meeting, San Francisco, California, December 15-19, 2014.
3. Villarini, G., Seasonal discharge forecasting over Iowa: Preliminary results for the Raccoon River, Iowa Water Conference, Ames, IA, March 2-3, 2015.

Problem and Research Objectives

Iowa is plagued by catastrophic natural hazards on a yearly basis, with the 2008 flood and the 2012 drought being two of the most recent extreme events affecting our state. Unfortunately, the question is not if, but when, the next extreme event will happen. There is little we can do to prevent flooding or droughts but we can improve our preparedness for these events. Improved readiness relies on the availability of information that would allow Iowans to make more informed decisions about the most suitable water management strategy. The proposed work aims to develop a framework to provide seasonal forecasts of discharge over Iowa with a lead time from one up to nine months. The availability of these forecasts would have major societal and economic impacts on hydrology and water resources management, agriculture, disaster forecasts and prevention, energy, finance and insurance, food security, policy-making and public authorities, and transportation.

Methodology

This proposal will advance our preparedness for flood and drought conditions over Iowa. Our approach aims at the development of a forecasting system to provide seasonal discharge values for one watershed in Iowa (Raccoon River at Van Meter). The methodology leverages the use of statistical models to describe discharge from low to high flow as described in Villarini and Strong (2014). These models use rainfall as well as row crop production acreage (used as a proxy for the characterization of the impacts of agricultural practices) as inputs. Seasonal rainfall forecasts will be based on one coupled ocean-atmosphere model, while the forecast of row crop production will be based on the value from the previous year (persistence forecast). The discharge forecast will have a lead time from one to up to nine months.

Principal Findings and Significance

Over the past year we have been making very significant progress towards accomplishing what proposed for Year 1. We have downloaded, processed and analyzed precipitation forecasts from the Geophysical Fluid Dynamics Laboratory (GFDL) model (FLORb01). This is the latest model version by GFDL, significantly improved over the previous versions (Vecchi et al. 2014, Jia et al. 2015).

Given the forecast data from the GFDL model, we have computed basin-averaged rainfall over the Raccoon River at Van Meter. Analyses are performed at the seasonal scale and we use precipitation records created by the PRISM Climate Group (Daly et al. 2002) as reference. Our focus so far has been on the spring and summer seasons, given that they are the seasons in which the largest number of flood events occurs. Figure 1 shows the comparison between the PRISM data and the GFDL forecast data for different lead times for spring (top panel) and summer (bottom panel).

It is clear that the GFDL precipitation forecasts do not exhibit the same year-to-year variations but a much narrower range of variability. The statistical model we have developed to characterize discharge, however, does not use the raw precipitation data, but rather the standardized anomalies (Villarini and Strong 2014). Figure 2 compares the standardized precipitation anomalies computed with respect to the 1980-2000 period. In this case, there is a much better agreement between observed and forecasted data. The year-to-year changes in the observational record are much better captured by the forecast data. There is also an overall better performance at shorter rather than longer lead times. This approach can be viewed as a way of bias-correcting the precipitation forecasts, and it appears to be effective at doing so.

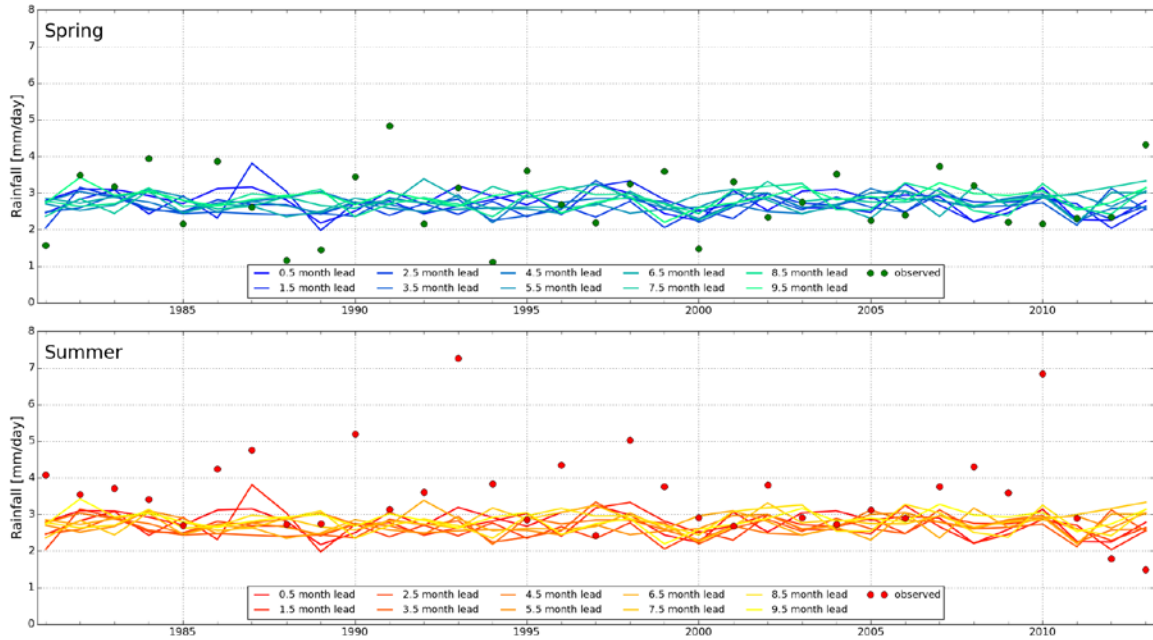


Figure 1. Comparison between spring (top panel) and summer (bottom panel) precipitation over the Raccoon River at Van Meter watershed. The circles represent the observations, while the different lines indicate the seasonal forecasts based on the GFDL-FLORb01 model. Different line colors refer to different lead times, with darker colors referring to shorter lead times.

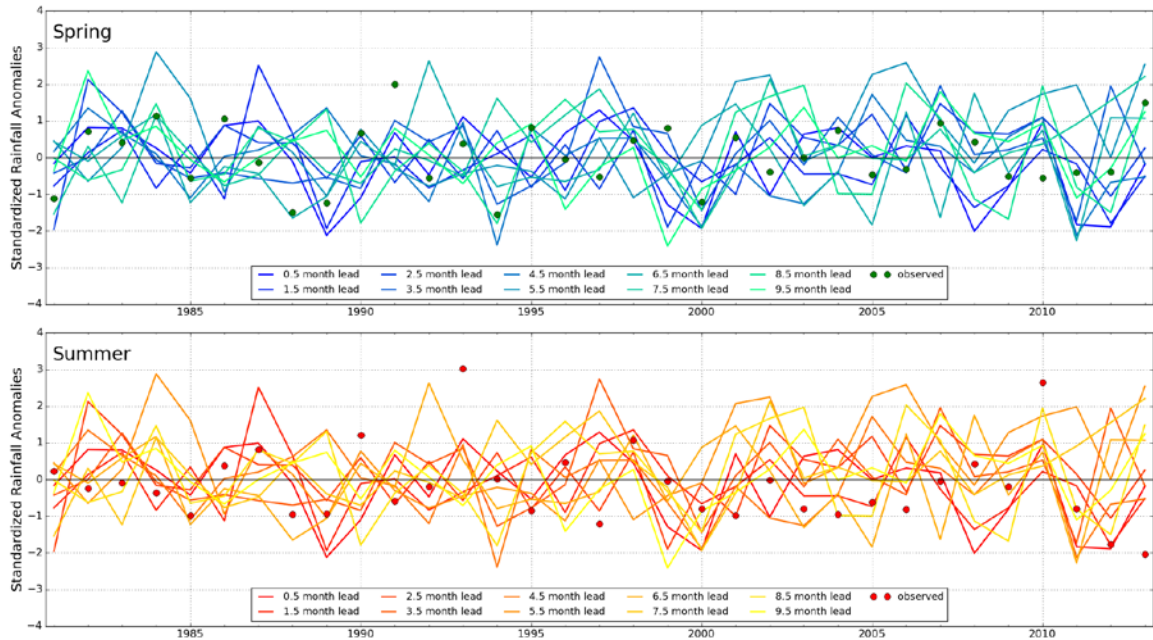
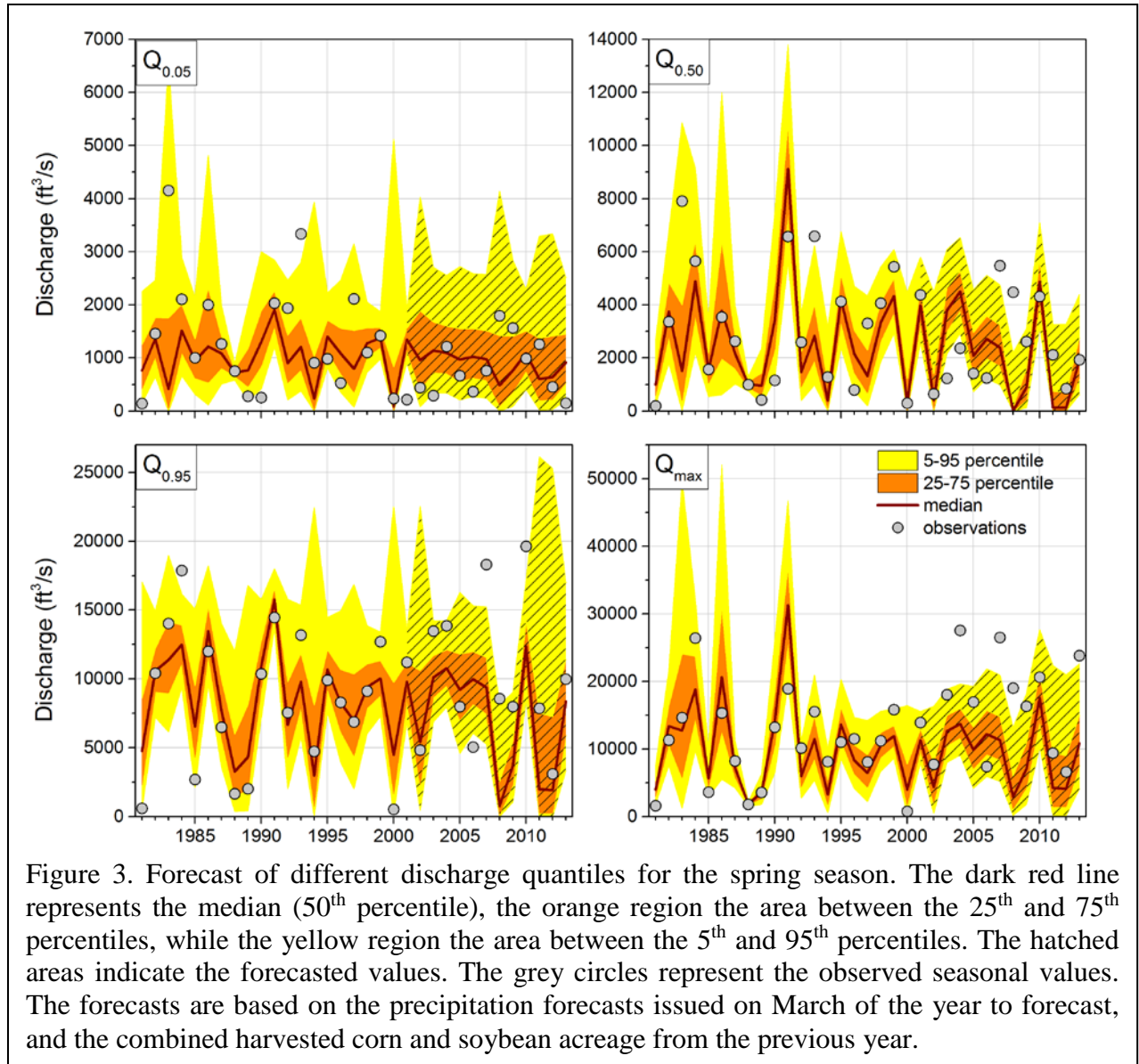


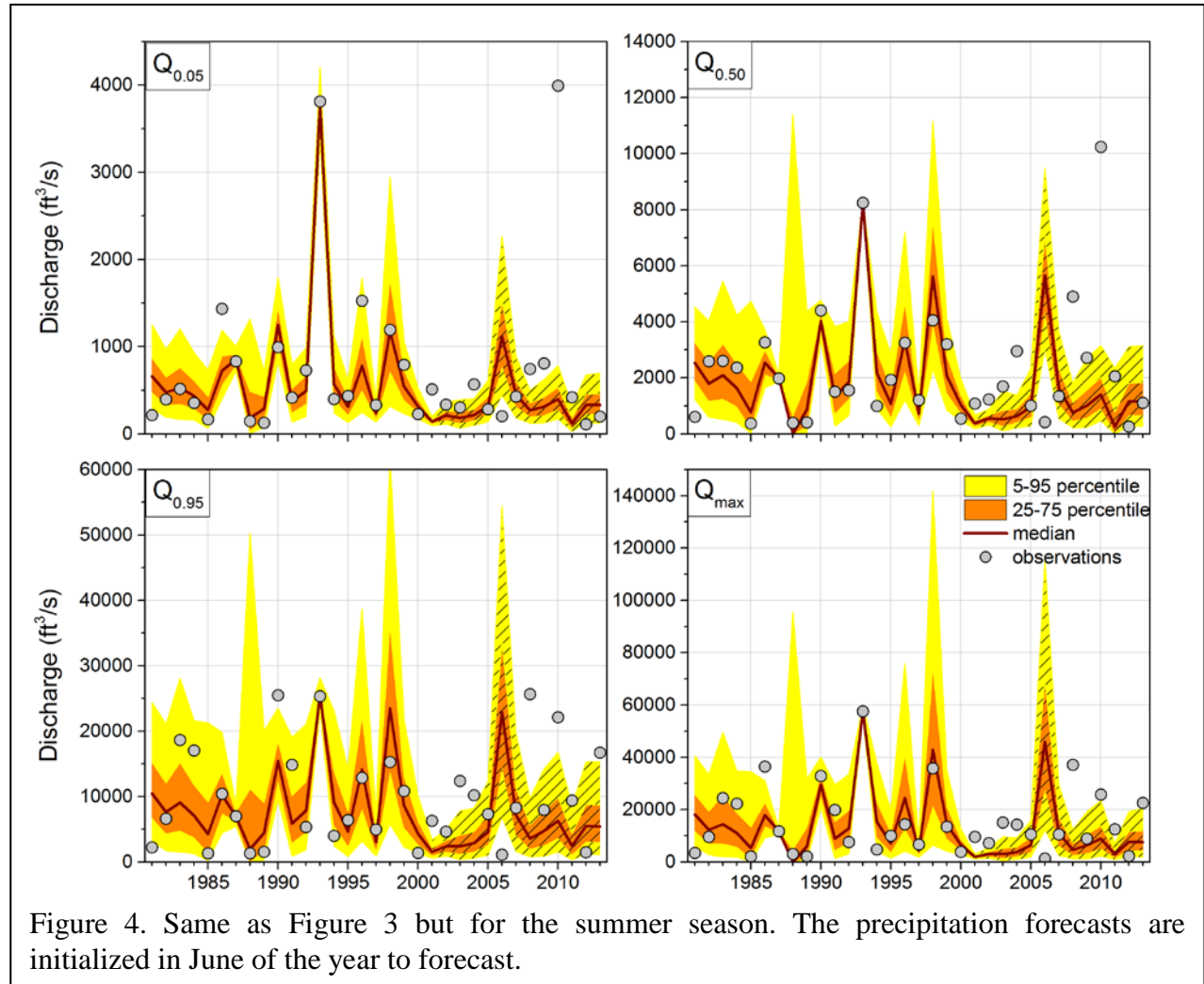
Figure 2. Comparison between spring (top panel) and summer (bottom panel) standardized precipitation anomalies over the Raccoon River at Van Meter watershed. The circles represent the observations, while the different lines the seasonal forecasts based on the GFDL- FLORb01 model. Different line colors refer to different lead times, with darker colors referring to shorter lead times. The anomalies are computed with respect to the 1980-2000 period.

The precipitation forecasts are used as predictor for the discharge model. We also include the combined harvested corn and soybean acreage from the previous year (persistence forecast) as additional predictor. Figures 3 and 4 show the discharge forecasts for different discharge levels, from low (top-left panels) to medium (top-right panels) to high (bottom panels) flow. This simple modeling framework is able to capture reasonably well the year-to-year changes in discharge at the seasonal level. When the statistical models of discharge are forced with observed precipitation values, they are able to well reproduce the observational records and the years with higher/lower values (solid filled areas in Figures 3 and 4).



The discharge forecasts, on the other hand, are dependent on the skill of the GFDL model in reproducing the precipitation records. As an example of the role played by the precipitation forecasts, consider the summer of 2006, which was a relatively dry season, but forecasted by the model to be rather wet (Figure 4). We tend to get better results when forecasting the median discharge (Figures 3-4, top-right panel), compared to the high or low flows. A thorough evaluation of these forecasts for all the seasons, lead times and discharge quantiles will be conducted over the next few months. Despite some of the shortcomings in the discharge forecasts,

these results are encouraging given that we will test improvements to the statistical models (e.g., inclusion of rainfall from the month prior to the season to forecast to capture the potential effects of antecedent soil moisture conditions).



Our effort over the past year was not just geared toward completing the tasks for Year 1 of the project, but we also wanted to get started on Year 2. We have already downloaded and organized precipitation forecasts from four additional modeling groups. The first step is a detailed evaluation of the skill of these models in forecasting precipitation. This work has already started, and performed over the continental United States. These results will provide indications about the skill

of these models in forecasting seasonal rainfall at different lead times. The rainfall forecasts from these additional models for the Raccoon River at Van Meter will be used as input for the statistical model of discharge, as detailed above for the GFDL model. This part of the work will be performed in Year 2, in which we will consider optimal ways of merging the rainfall forecasts from the different modeling groups. We will also examine the generalization of these modeling framework and results to other locations around Iowa.

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Student support

- Nancy Barth (Ph.D.)
- Gregory Karlovits (Ph.D.)
- Anda Shi (undergrad)

Outcomes since the beginning of the project

Manuscript:

- Slater, L., G. Villarini, A.A. Bradley, and G.A. Vecchi, Statistical forecasting of seasonal discharge in an agricultural watershed in Iowa, 2015 (in preparation).

Abstracts to conferences:

- Karlovits, G.S., G. Villarini, A.A. Bradley, and G.A. Vecchi, Diagnostic evaluation of NMME precipitation and temperature forecasts for the continental United States, 95th American Meteorological Society Annual Meeting, Phoenix, Arizona, January 4-8, 2015.
- Karlovits, G.S., G. Villarini, A. Bradley, and G.A. Vecchi, Diagnostic evaluation of NMME precipitation and temperature forecasts for the continental United States, AGU Fall Meeting, San Francisco, California, December 15-19, 2014.
- Villarini, G., Seasonal discharge forecasting over Iowa: Preliminary results for the Raccoon River, Iowa Water Conference, Ames, IA, March 2-3, 2015.

Cost-Effectiveness of Reverse Auctions for Watershed Nutrient Reductions in the Presence of Climate Variability

Basic Information

Title:	Cost-Effectiveness of Reverse Auctions for Watershed Nutrient Reductions in the Presence of Climate Variability
Project Number:	2014IA255B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	IA-004
Research Category:	Water Quality
Focus Category:	Economics, None, None
Descriptors:	None
Principal Investigators:	Adriana Valcu, Philip W. Gassman, Catherine L. Kling

Publications

There are no publications.

Cost-Effectiveness of Reverse Auctions for Watershed Nutrient Reductions in the Presence of Climate Variability

by Adriana Valcu¹, Phillip Gassman, and Catherine Kling

Progress report

Problem statement

The Climate Change Impacts on Iowa 2010 report shows that, during the last few decades, Iowa's climate experienced significant variability in the precipitation patterns with wetter springs and dryer falls, increase in dew point humidity levels, higher nighttime minimum temperatures, and a higher number of frost free days. Some of these changes have a positive impact on Iowa's agriculture (increase in the crop production) but others have a negative impact on soil or water quality.

The extreme rainfall events have resulted in higher erosion of topsoil. For example, in 2008, the soil erosion rates for some Iowa areas were as high as 50 tons per acre compared to the average rate of 5 tons per acre (Climate Change Impact on Iowa 2010). Moreover, more intense rainfall increases the surface water runoff and subsurface drainage, thus resulting in more sediment and water pollution. It has been shown that there is a correlation between the nitrate loss and the amount of precipitation (Climate Change Impact on Iowa 2010).

At the national level, reducing the nitrogen and phosphorus loadings from agricultural Midwest region is an important objective for reducing the size of the hypoxic zone in the Gulf of Mexico. At the Iowa state level, in 2010, Iowa Department of Agriculture and Land Stewardship and the College of Agriculture and Life Sciences at Iowa State University signed a partnership for developing a statewide nutrient reduction strategy for Iowa. The overall goal is a 45% reduction in the nitrogen and phosphorus loads that reach the Mississippi River (Iowa Nutrient Reduction Strategy, May 2013).

Given the implications of climate change and variability on water and soil quality, it is important for watershed managers, stakeholders and policy makers to understand not only the effectiveness of individual conservation practices in improving water quality but also the cost-effectiveness of watershed level policy programs designed for the implementation of conservation practices.

Since the current regulatory framework supports only voluntary approaches, designing incentives programs that are both cost efficient and budgetary cost effective is critical. Cost-efficiency implies getting the right mix of program participants and their activities in order to ensure that society's resources are not being wasted in achieving a particular environmental goal while the budgetary cost-effectiveness implies stretching conservation funds as far as possible, minimizing the unnecessary transfer of funds to private landowners.

Among the various market instruments proposed as resource and cost revelation mechanisms, competitive biddings, also referred as "reverse auctions" or procurement auctions, have come to the researchers and policy makers' attention. Competitive bidding mechanisms induce the landowners to submit the bids close to their opportunity costs thus increasing the

¹ amvalcu@iastate.edu

budgetary cost effectiveness and revealing the true costs of adopting different conservation practices.

The objectives

The objectives of this study are (1) to determine how the effectiveness of different conservation practices will be affected by climate variability and (2) consider and simulate the cost efficiency of a reverse auction as an incentive mechanism designed to improve water quality at the watershed level in the presence of climate change. This study will consider the cost-efficiency of reverse auction program designed for improving water quality in the Boone River Watershed (BRW).

Methodology

Several steps need to be implemented before simulating the costs efficiency of a reverse auction as an incentive mechanism for improving water quality.

1. Identifying a set of agricultural practices (conservation actions) that are efficient in reducing nutrient (nitrogen and phosphorus). This set includes: no till, reducing the fertilizer application rates by 20 %, cover crops, switchgrass, miscanthus, and land retirement.
2. Calibrating the watershed using a watershed-based modeling framework.
3. Identifying possible global circulation models (GCM's) for climate change and downscaling them at the watershed level. We identified four different mid-century (2046-2065) climate scenarios²: CGCM3_T47, CGCM3_T63, MIROC_MED, and MIROC_HI.
4. Simulating thousands of possible watershed configurations for a 20-year period: 1993-2013 under current climate, and 2046-2065 under each future climate scenario.
5. Identifying costs for each conservation practices
6. Using a system of points together with cost data to evaluate the cost efficiency of a reverse auction. The system of points will be estimated both under the current climate patterns as well under different future climate scenarios. A point estimates how efficient a conservation practice is in reducing nutrient runoff at the field level.
7. We will simulate the costs and environmental outcomes of a reverse auction.

Principal Findings and Significance for the project year 3/1/14-2/28/15

We were able to complete significant work related to points 1 to 7.

1. Identifying a set of conservation practices

Table 1 summarizes the set of conservation practices used in our simulations. The set of conservation practices is extended by including combinations of the initial practices (i.e., no till and cover crops). Next, we create uniform watershed scenarios (each field in the watershed is assigned the same conservation practice), and simulate these scenarios using our modeling framework, SWAT.

² The choice of GCMs for this study was determined in collaboration with Dr. Raymond Arritt of the Iowa State Univ. Agronomy Dept., who we have been working with in other climate change related simulation studies.

Table 1: Conservation practices and their performance under uniform watershed scenarios

	Current climate		CGCM3_T63		CGCM3_T47		Miroc_med		Miroc_hi	
	Total N (tonnes)	% N red.	Total N (tonnes)	% N red.	Total N (tonnes)	% N red.	Total N (tonnes)	% N red.	Total N (tonnes)	% N red.
Baseline	4,694.08	-	4,954.0	-	5,093.6	0.00	3,974.3	0.00	3,633.5	0.00
No till	4,300.90	8.38	4,556.7	8.02	4,887.9	4.04	3,722.9	6.32	3,541.1	2.54
Cover Crops	2,512.11	46.48	2,775.9	43.97	2,915.3	42.76	1,802.4	54.65	1,558.8	57.10
Reduced nitrogen fertilizer (20%)	4,279.75	8.83	4,430.4	10.57	4,380.8	13.99	3,393.8	14.61	3,028.1	16.66
No till and reduced nitrogen fertilizer	3,862.05	17.73	4,219.9	14.82	3,980.6	21.85	3,140.9	20.97	2,928.1	19.41
Cover crops and reduced nitrogen fertilizer rate	2,512.11	46.48	2,775.9	43.97	2,915.3	42.76	1,802.4	54.65	1,558.8	57.10
No till, Cover crops, and reduced nitrogen fertilizer rate	1,765.13	62.40	2,018.6	59.25	2,094.5	58.88	1,228.3	69.09	1,023.1	71.84
Land Retirement	561.99	88.03	1,107.0	77.66	961.4	81.12	914.0	77.00	913.8	74.85
Miscanthus	336.37	92.83	337.6	93.19	321.4	93.69	249.9	93.71	196.2	94.60
Switchgrass	821.90	82.49	680.0	86.27	485.3	90.47	584.8	85.29	506.4	86.06

Table 1 includes the results of these simulations for nitrogen. Several findings can be highlighted:

- More nitrogen runoff is expected under two future climate scenarios (CGCM3_T63 and CGCM3_T63).
- Land Retirement, Miscanthus, and Switchgrass have the highest potential to decrease nitrogen runoff.
- Relative to current climate, No till is less efficient when future climate scenarios are considered
- Relative to current climate, Cover Crops are less efficient under CGCM3 scenarios, but more efficient under the MIROC scenarios.

2. Boone River watershed SWAT baseline testing results

The current Boone River watershed SWAT baseline testing builds on original testing of SWAT for the Boone River watershed that was reported in Gassman (2008). The original SWAT applications for the Boone River watershed were performed with SWAT version 2005 (SWAT2005) as reported in Gassman (2008). Successful streamflow testing results were obtained in that work although nitrate simulation problems were encountered with that code due to underestimation of nitrate transport via subsurface tile lines. The present SWAT simulations are being performed with an updated SWAT version 2012 code (SWAT2012, Release 6150 that contains corrected algorithms that more correctly simulate movement of nitrate through subsurface tile lines as well as numerous other enhancements that were not present in the SWAT2005 code.

An initial indicator that was examined in the current model testing was the estimated 30-year average corn and soybean yields estimated by SWAT across all of the Boone River watershed cropland landscapes. These crop yields reported by SWAT were compared to county average yields reported by USDA-NASS (USDA-NASS, 2015) for the six counties that the Boone River watershed is located in, by converting the SWAT crop yields to bu/ac as follows:

$$(1) \text{ Yield (bu/a)} = \text{SWAT_Yield} * 0.4461 * 2000 * \text{moisture} / \text{unit conversion factor}$$

Where the SWAT_yield is the crop dry weight yield (m t/ha), moisture reflects an assumed moisture content of 13% (factor = 1.13) and the unit conversion factor is 55.7 for corn and 60 for soybean.

Using this equation and corresponding factors, the predicted average annual SWAT corn and soybean yields of approximately 10 m t/ha and 3 m t/ha convert to 180 bu/ac and 50 bu/ac, respectively. These converted SWAT yields are generally equivalent to 2014 USDA-NASS corn and soybean yields of 177 bu/ac and 47.4 bu/ac averaged over Hamilton, Hancock, Humboldt, Kossuth, Webster and Wright counties, which are the six counties that the Boone River watershed is located in. This can be viewed as only a rough comparison because no attempt was made to compute areal weighted USDA-NASS crop yields based on the percentage of the Boone River watershed that was located in each county, plus the USDA-NASS yields considered here are based only on the most recent reporting year of 2014. However, the comparison does underscore that the long-term SWAT average crop yields are consistent with current crop yields in the Boone River watershed region.

The streamflow testing for the Boone River watershed is based on the “alternative runoff curve number (RCN) approach” reported in Gassman (2008), in which the soil water retention parameter is estimated as function of accumulated evapotranspiration rather than antecedent moisture conditions (Williams et al., 2012). Simulated versus measured streamflow comparisons are presented on an annual and monthly basis in Figures 1 and 2 for a U.S. Geological gauge site located just south of Webster City in the southern portion of the Boone River watershed. The graphical results indicate that SWAT accurately replicated annual and monthly streamflow patterns across the 30-year simulation period. Statistical comparisons were also computed between the SWAT-predicted and measured streamflows using the well-known coefficient of determination (R^2) and Nash-Sutcliffe efficiency (NSE) statistics that are described by Krause et al. (2005). The R^2 /NSE values were 0.97/0.96 for the over the 30-year annual comparisons and 0.92/0.91 for the 30-year monthly comparisons which more than meet successful hydrological model testing criteria as suggested by Moriasi et al. (2007).

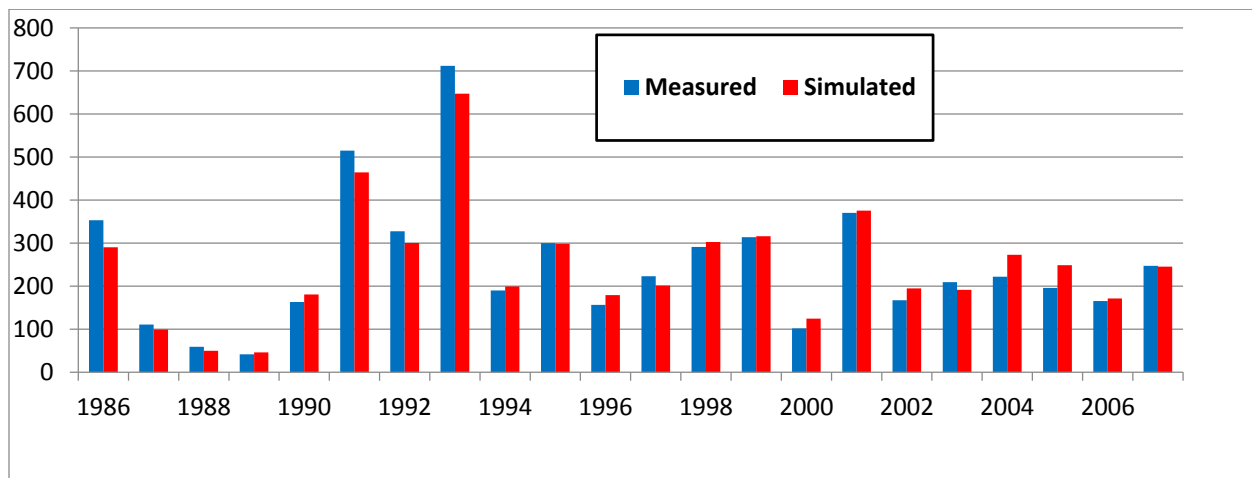


Figure 1. Simulated versus measured annual streamflow comparisons for the USGS gauge located south of Webster City, Iowa.

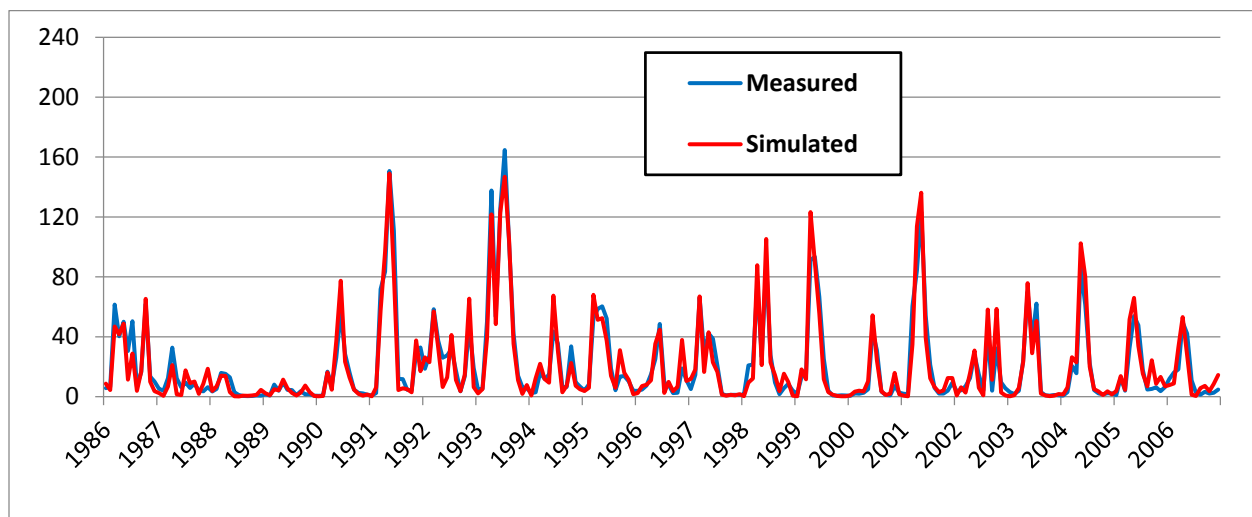


Figure 2. Simulated versus measured monthly streamflow comparisons for the USGS gauge located south of Webster City, Iowa.

Additional testing has been performed of pollutant outputs generated in the current SWAT application for the Boone River watershed. The majority of the predicted nitrate losses to the Boone River stream system are occurring via subsurface tile drainage, which is the expected dominant pathway as noted above. Comparisons of sediment, nitrate, total P and other pollutant loss indicators have been compared with load estimates derived from pollutant concentrations measured at the watershed outlet. These comparisons will be reported in more detail in the final project report.

3. Identifying possible global circulation models (GCM's) for climate change and downscaling them at watershed level.

The future climate projections were taken from results of coupled atmosphere-ocean general circulation models (GCMs) that participated in the World Climate Research Programme Coupled Model Intercomparison Project phase 3 (CMIP3; LLNL, 2013). Although newer results are now available from models participating in phase 5 of that project (i.e., CMIP5; Taylor, 2012), it has been found in previous research that the patterns of temperature and precipitation change are quite similar between the CMIP3 and CMIP5 models (Knutti and Sedlacek, 2013).

We are using the horizontal grid spacings (IPCC, 2007a), equilibrium climate sensitivity (ECS; IPCC, 2007b) and transient climate response (TCR; IPCC, 2007b) for the four GCMs listed in Table 1. The TCR is the warming around the time that carbon dioxide has doubled from its pre-industrial value but before the system has adjusted to slow feedbacks. Although ECS is probably a more widely-known model characteristic, TCR may be a more appropriate measure given that our period of interest (2046-2065) is around the time of CO₂ doubling before the system has equilibrated to all feedbacks (Frame et al., 2005; 2014).

Current climate is taken as the years 1981-1999 from each model's results for CMIP3 "Climate of the 20th Century" simulations (for models that performed more than one run the first ensemble member was used). These simulations included observed forcings from greenhouse gases, natural and anthropogenic aerosols, solar variability, ozone and land use changes for the period 1900-2000. For future climate we use each model's results for the years 2046-2065 from A1B climate scenario. This scenario specifies that emissions of the major greenhouse gases (carbon dioxide, methane and nitrous oxide) increase through the middle of the 21st century and stabilize or decline thereafter, with carbon dioxide concentrations stabilizing at 720 ppmv. Solar radiation and volcanic aerosols are held at their 2000 values throughout the 21st century. An overview of the CMIP3 experiment design is given elsewhere (Meehl et al., 2007).

For temperature and precipitation we used monthly downscaled results^[1] that were created for each of the GCMs in Table 2. The downscaling method used was bias correction with spatial disaggregation (BCSD). This method removes precipitation and temperature biases for each of the model projections in the present climate through quantile matching, then interpolates forecast anomalies for a given monthly time step to a 1/8 degree latitude-longitude grid and superimposed on the observed baseline climate (which results in roughly one climate grid point for each of the 30 subwatersheds configured in the Boone River watershed SWAT application). Future values of other variables required by SWAT (monthly solar radiation, dew point and wind speed) were generated by superimposing the difference between each GCM's future (2046-2065) and current (1981-2000) climate onto observed historical records; this is the widely used "delta" (also called "change factor") method. Further details regarding the BCSD approach and other aspects of inputting the climate projections in SWAT are described in previous research (Panagopoulos et al., 2014; 2015).

Table 2. Name, institutional information, country of origin, grid spacing, and ECS and TCR data for the seven global circulation models (GCMs) used for the OTRB climate change analyses.

Model	Institution	Country	Grid spacing ^a	ECS (TCR) ^b
CGCM3.1	Canadian Centre for Climate Modelling and Analysis	Canada	T47 (2.8° x 2.8°)	3.4 (1.9)
CGCM3.1	Canadian Centre for Climate Modelling and Analysis	Canada	T63 (1.9° x 1.9°)	3.4 (NA)
MIROC3.2 (medres)	University of Tokyo, National Institute for Environmental Studies, and Frontier Research Center for Global Change	Japan	T42 (2.8° x 2.8°)	4.0 (2.1)
MIROC3.2 (hires)	University of Tokyo, National Institute for Environmental Studies, and Frontier Research Center for Global Change	Japan	T106 (1.1° x 1.1°)	4.3 (2.1)

^aGrid spacing is the latitude-by-longitude spacing of the computational grid, or the spectral truncation and near-equatorial latitude-by-longitude spacing of the corresponding Gaussian grid for spectral models.

^bECS and TCR are equilibrium climate sensitivity and transient climate response in units of K (Randall et al., 2007), with "NA" indicating values are not available.

4. Simulate watershed scenarios

We create 5,000 watershed scenarios by randomly assigning a conservation practice to each field in the watershed. Next, we use SWAT to simulate the nitrogen values for each scenario. Additionally, each scenario was evaluated under each climate scenario, including the current climate.

5. Costs

Table 3 summarizes the per acre costs and data sources.

Table 3: Cost of conservation practices

Conservation practice	Cost (\$/acre)	Cost source
No Till	5.1	Kling et al. (2005)
Cover Crop	25	T. Kaspar ³
Reduced fertilizer	7.25	Sawyer et al.(2006); Libra et al.(2004)
Land retirement	196.42	Kling et al. (2005)
Switchgrass	95.78	http://www.extension.iastate.edu/agdm/crops/pdf/a1-29.pdf
Miscanthus	159.66	https://www.extension.iastate.edu/agdm/crops/pdf/a1-28.pdf

³ Personal communication

6. Estimating the point coefficients

We use SWAT simulation results to estimate a system of point coefficients.

$$\Delta N_i \cong \sum_j^J a_{i,j} P_j \quad i = 1 \text{ to } 5000, j = 1 \text{ to } 10$$

Where:

- i represents the number of simulations
- j represents the number of practices
- ΔN_i represents the change in nitrogen relative to the baseline for each simulation
- $a_{i,j}$ represents the total area allocated to practice j in simulation i
- P_j represents the point coefficient associated with practice j ; to be determined.

Table 4: Point estimates (reduced N kg/ acre)

Conservation practice	Climate scenarios				
	Current	CGCM3_63	CGCM3_47	MIROC_med	MIROC_hi
Baseline	0.15	0.21	0.19	0.15	0.18
No till	0.39	0.21	0.68	0.28	0.04
Cover Crops	4.72	3.93	3.70	3.50	3.59
Cover Crops and No till	5.05	3.93	3.92	3.50	3.61
Reduced nitrogen fertilizer (20%)	0.72	1.03	0.89	0.92	0.97
No till and reduced nitrogen fertilizer	1.29	1.40	1.67	1.34	1.14
Cover crops and red. fert. rate	5.23	4.73	4.33	4.22	4.17
No till, Cover crops, and red. fert.rate	5.56	4.79	4.57	4.23	4.23
Land Retirement	7.74	6.90	6.92	5.29	4.65
Switchgrass	7.27	7.74	7.82	6.01	5.51
Miscanthus	8.32	8.39	8.19	6.57	6.06

We use ordinary least square method to estimate the point system. Table 4 summarizes the estimation results under each climate scenario. The estimation results follow almost the same pattern as the results summarized in Table 1, with land retirement, switchgrass, and miscanthus being the most efficient practices in reducing nitrogen. The point estimates for the bundles of practices are not necessarily equal to the sum of the point estimates for individual components.

Cover crops and land retirement are less efficient under the future climate scenarios; their future climate estimates are lower than the current climate estimates. Mixed trends are observed for switchgrass and miscanthus: they are more efficient under CGCM3 climate scenarios, but less efficient under MIROC climate scenarios.

Any notable achievements or awards resulting from work on this project

No awards resulted from this project.

Student support provided by the project (please include student level (i.e. undergrad, masters, phd, or post-doc):

Not applicable

Publication citations associated with the project:

The project is still work in progress, with the final output being intended to be submitted to a relevant journal.

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Development of a Comprehensive Hazard to Loss Modeling Methodology for the Residential Damage Associated with Inland Flooding from North Atlantic Tropical Cyclones

Basic Information

Title:	Development of a Comprehensive Hazard to Loss Modeling Methodology for the Residential Damage Associated with Inland Flooding from North Atlantic Tropical Cyclones
Project Number:	2014IA257G
USGS Grant Number:	G14AS00014
Start Date:	9/1/2014
End Date:	8/31/2016
Funding Source:	104G
Congressional District:	IA002
Research Category:	Climate and Hydrologic Processes
Focus Category:	Floods, Economics, Climatological Processes
Descriptors:	None
Principal Investigators:	Gabriele Villarini, Jeffery Czajkowski, Erwann MichelKerjan

Publications

There are no publications.

Problem and Research Objectives

We propose to develop statistical models to describe the relation between inland flooding associated with North Atlantic tropical cyclones (TCs) and impacts (claims and losses) in the United States. This is a topic of high socio-economic relevance, but regrettably has received very little attention as most U.S. TC loss assessment efforts are focused on coastal areas. Its importance has unfortunately been highlighted in the recent past, with significant inland flooding associated with Hurricanes Irene (2011) and Isaac (2012). These hurricanes, however, are not isolated cases, but are representative of much larger set of events with large impacts (e.g., Rappaport 2000; Pielke and Klein 2005; Pielke et al. 2008; Changnon 2008; Jonkman et al. 2009; Czajkowski et al. 2011, 2013; Mendelsohn et al. 2012; Peduzzi et al. 2012).

The main outcomes of the proposed research are: 1) at a fairly granular level the identification of the areas that are more at risk from inland flooding from North Atlantic TCs; 2) the characterization of the extent and magnitude of these events; 3) the development of statistical models relating flood magnitude to direct economic losses importantly controlling for the associated exposure and vulnerability aspects over the period 2001-2012; 4) the use of the resulting empirical relationships to perform sensitivity analysis examining the potential impacts of pre-2000 TCs under the current level of exposure and vulnerability. The proposed work will provide information instrumental for the assessment and understanding of the changes in TC flood hazard (both in terms of spatial location and magnitude) over the 20th century, together with a quantification of the associated impacts.

Methodology

The goal of our work is to develop a data-driven climatology of inland flooding associated with North Atlantic TCs and to model the associated impacts in the United States. Significantly, we utilize a data-driven approach to flood hazard characterization based on discharge observations from a dense network of stream gaging stations, leveraging the wealth of discharge data collected and disseminated by the U.S. Geological Survey (USGS). Moreover, we have a unique access to the federally-run National Flood Insurance Program (NFIP) data - flooding in the United States is mainly insured by this public program - to allow for examination of flood claims, damage and relevant exposure data. The focus of our work is on the area of the continental United States east of the Rocky Mountains.

The analysis of flooding associated with TCs at the regional scale requires accounting for the dependence of discharge on drainage area. Here we follow the approach described in Villarini et al. (2014) and normalize the peaks caused by TCs by the at-site 2-year flood peak. The selection of the 2-year return period is due to two main reasons: 1) it is roughly the discharge value corresponding to bankfull conditions, with values larger than it pointing to out-of-bank flow; 2) it can be estimated reasonably accurately from the data using a relatively small window. One of the issues with the flood ratio is that it does not generally provide information regarding the severity of the flood event. To address this issue and similar to Villarini et al. (2014), we will use the flood status classification by the National Weather Service (NWS), and consider four categories in the analysis (see next section for results related to this issue). We define as flooding associated with a TC the largest flood peak measured by a station located within 500 km from the center of the storm during a time window of two days prior and seven days after the passage of the storm (e.g., Villarini et al. 2014).

The four basic components of natural hazard risk assessment are: hazard, exposure, vulnerability and loss. In modeling the number of flood claims incurred (predictand), we develop statistical models in which the response variable is related to different predictors. For each impacted area of the storm, the covariates we are currently considering (amongst others) include the above-defined flood ratio and its NWS classification, the number of housing units, the total population, the number of flood insurance policies-in-force, event-specific storm fixed effects, geographic-specific impacted area fixed effects, and areas of high flood risk as designated by a 1996 Natural Disaster Study conducted by the Federal Emergency Management Agency on behalf of the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (<https://www.npms.phmsa.dot.gov/DisasterData.aspx>). These models will represent losses and insurance claims for 30 North Atlantic TCs for the 2001-2012 period.

Principal Findings and Significance

Over the past six months (the project started on 1 September 2014) we have dedicated a lot of time and effort in the downloading, screening and organization of the data needed to complete the analyses. We have downloaded the daily discharge data for all the USGS stream gaging stations for the entire available period of record. There are over 23000 USGS stream gaging stations, 22000 of which within the continental United States (Figure 1).

We have screened all these stations for completeness, record length and geographic location. More specifically, we have selected only the stations that have been within 500 km of the center of circulation of any North Atlantic TC over the 1980-2013 period and with at least 20 years of complete data over the same period. We also subset the stream gaging stations focusing on those with NWS qualifying flag (see previous section). There are about 3000 USGS stations with NWS

qualifying flood information, at least 20 years of complete daily data and within 500 km of the center of circulation of a North Atlantic TC during the 1980-2013 period (Figure 2).

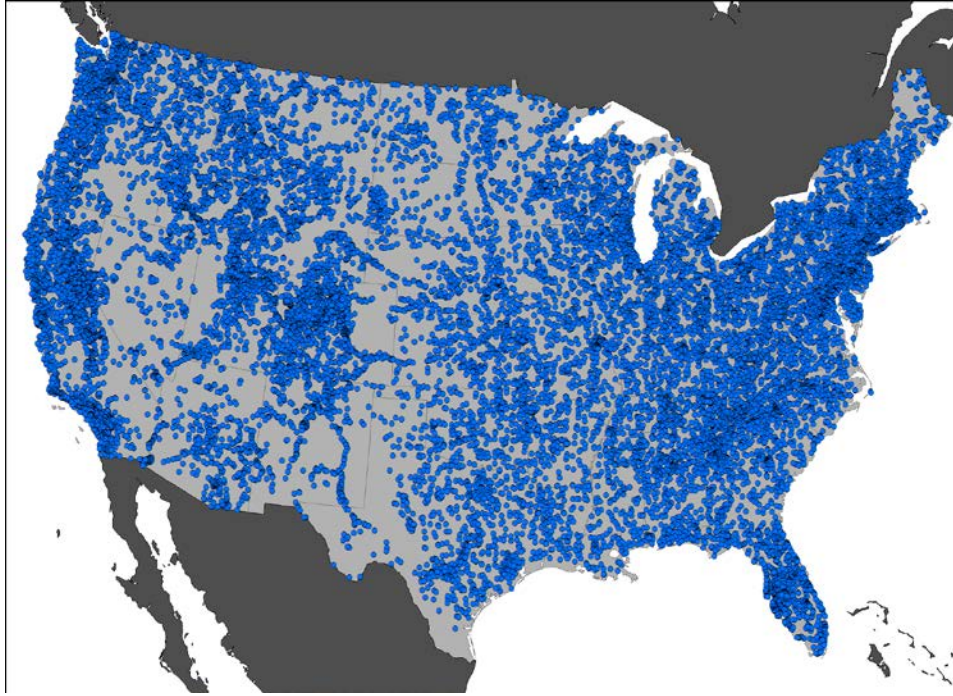


Figure 1. Map showing the location of all the USGS stream gaging stations available within the continental United States.

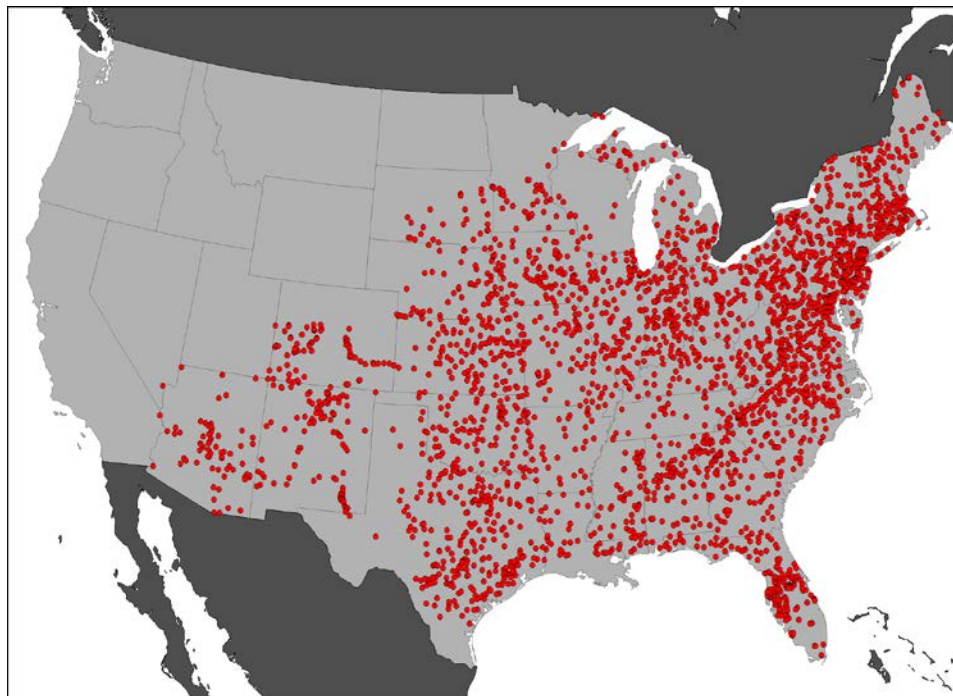
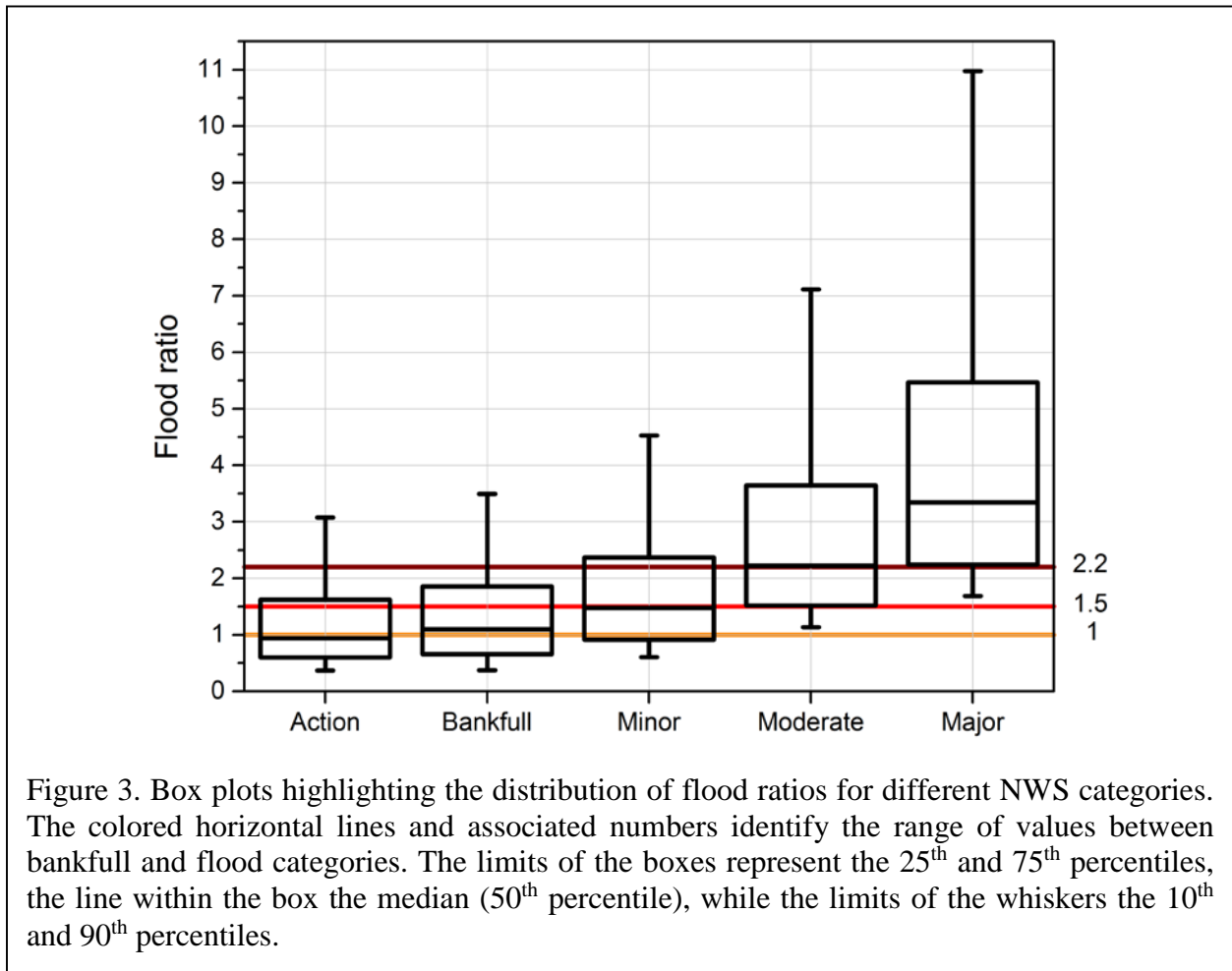
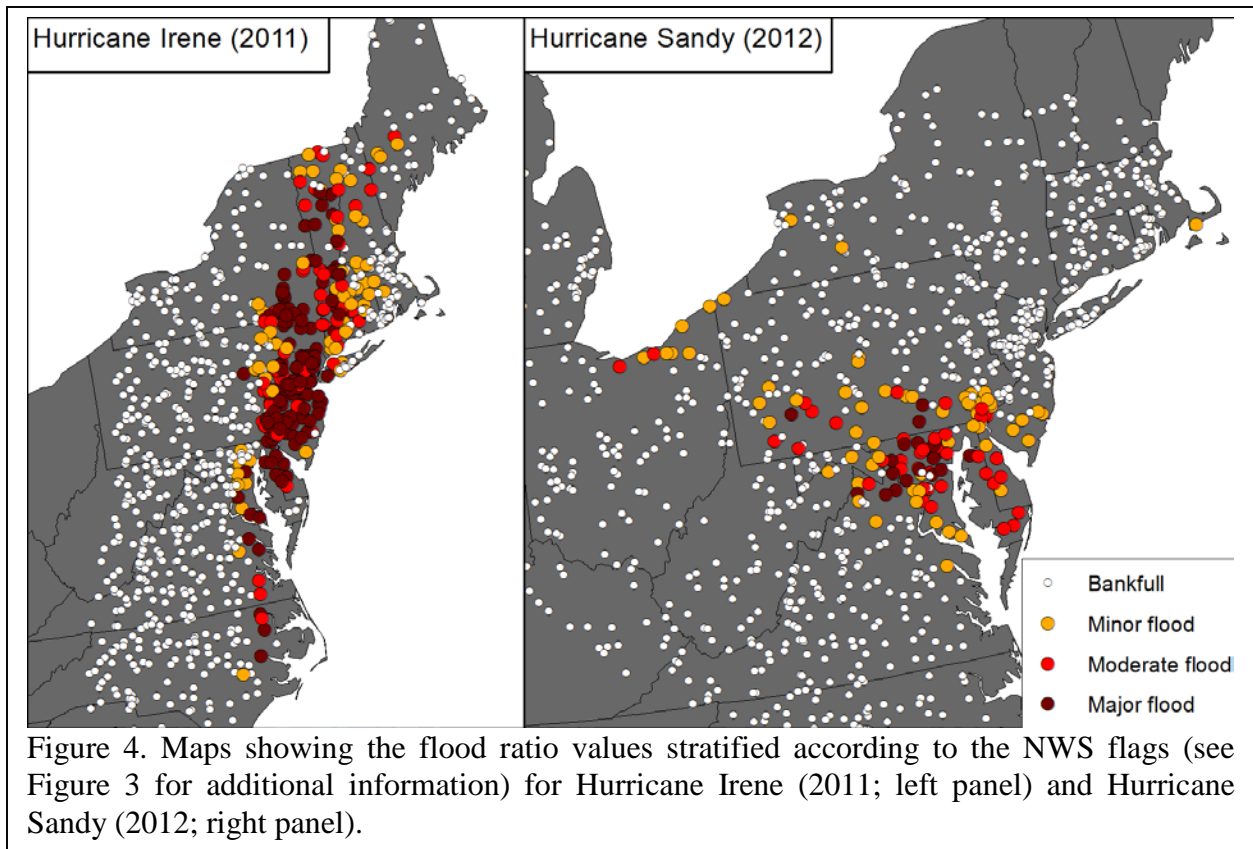


Figure 2. Map showing the location of all the USGS stream gaging stations with NWS qualifying flood information, at least 20 years of complete daily data and within 500 km of the center of circulation of a North Atlantic TC during the 1980-2013 period.

After we successfully downloaded, screened and organized all the discharge data, we computed the flood ratio values corresponding to different flood levels as categorized by the NWS. Figure 3 shows the variability that we could expect for different “flood” levels. Based on these results, we consider flood ratio values smaller than 1 as indication of water within the banks (“bankfull”), values between 1 and 1.5 as “minor flooding,” values between 1.5 and 2.2 as “moderate flooding,” values larger than 2.2 as “major flooding.”



For every TC passing within 500 km of the U.S. Coast, we can then compute the flood ratio value for all the stream gage stations within a 500-km buffer around the storm track. Figure 4 highlights the results for two of these storms, Hurricane Irene (2011) and Hurricane Sandy (2012).



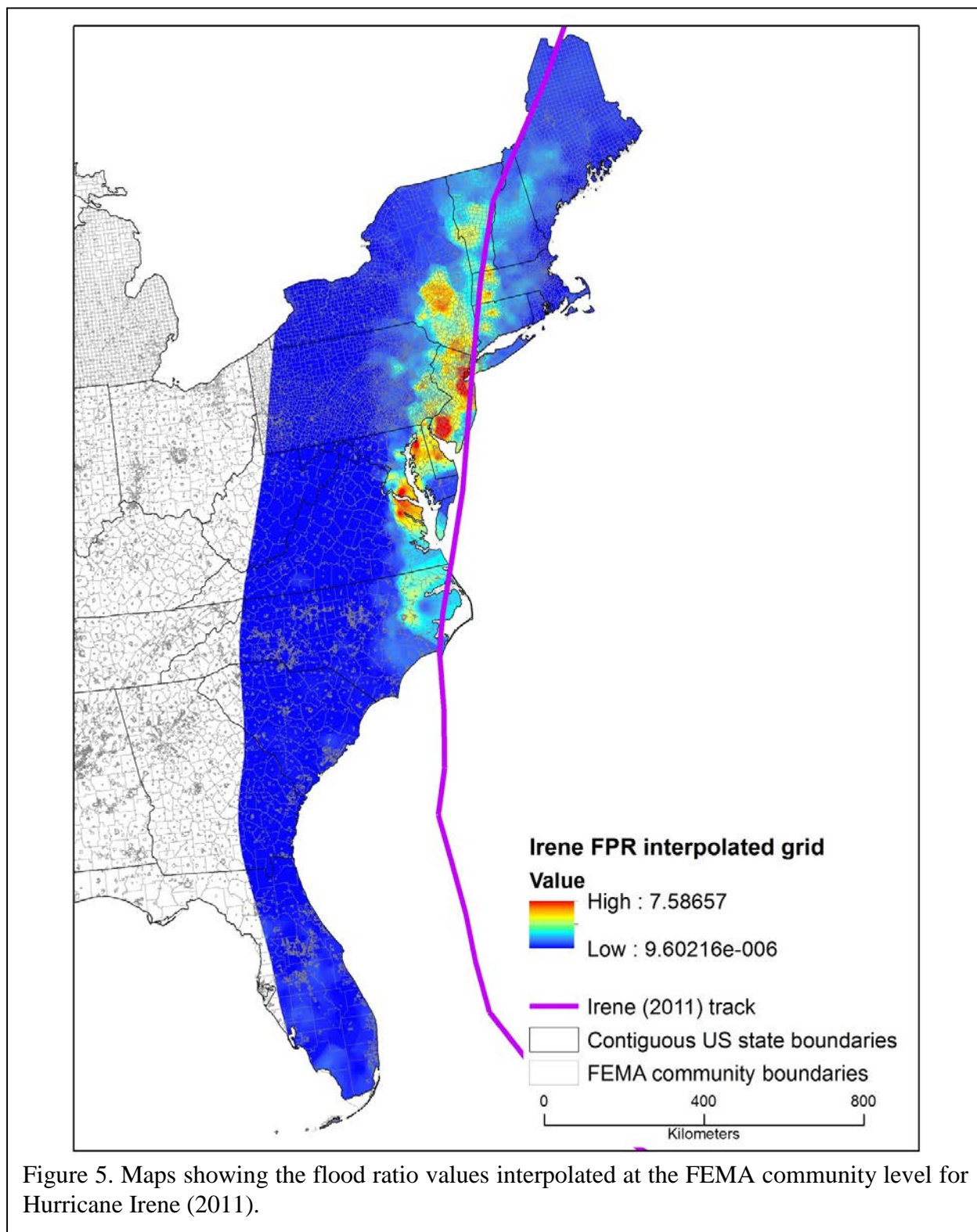
Hurricane Irene caused major flooding over large areas of the eastern United States (Figure 4, left panel), in particular in New Jersey; the effects of this storm were felt as far north as Vermont and Maine. On the hand, Hurricane Sandy caused the largest flooding in Delaware, Maryland and into New York (Figure 4, right panel). This is the kind of information we have for all the North Atlantic TCs affecting the United States during the 1980-2013 period.

This individual stream gauge 2-year flood peak hazard information forms the basis for the inland flood risk assessment via our statistical claim loss modeling. We have initiated this risk assessment for a subset of our identified North Atlantic TCs – Ike 2008, Irene 2011, and Isaac 2012. We describe the process and initial results below.

The associated loss data for each TC event are the actual insurance claims incurred by the US National Flood Insurance Program (NFIP). In the United States, coverage for flood damage

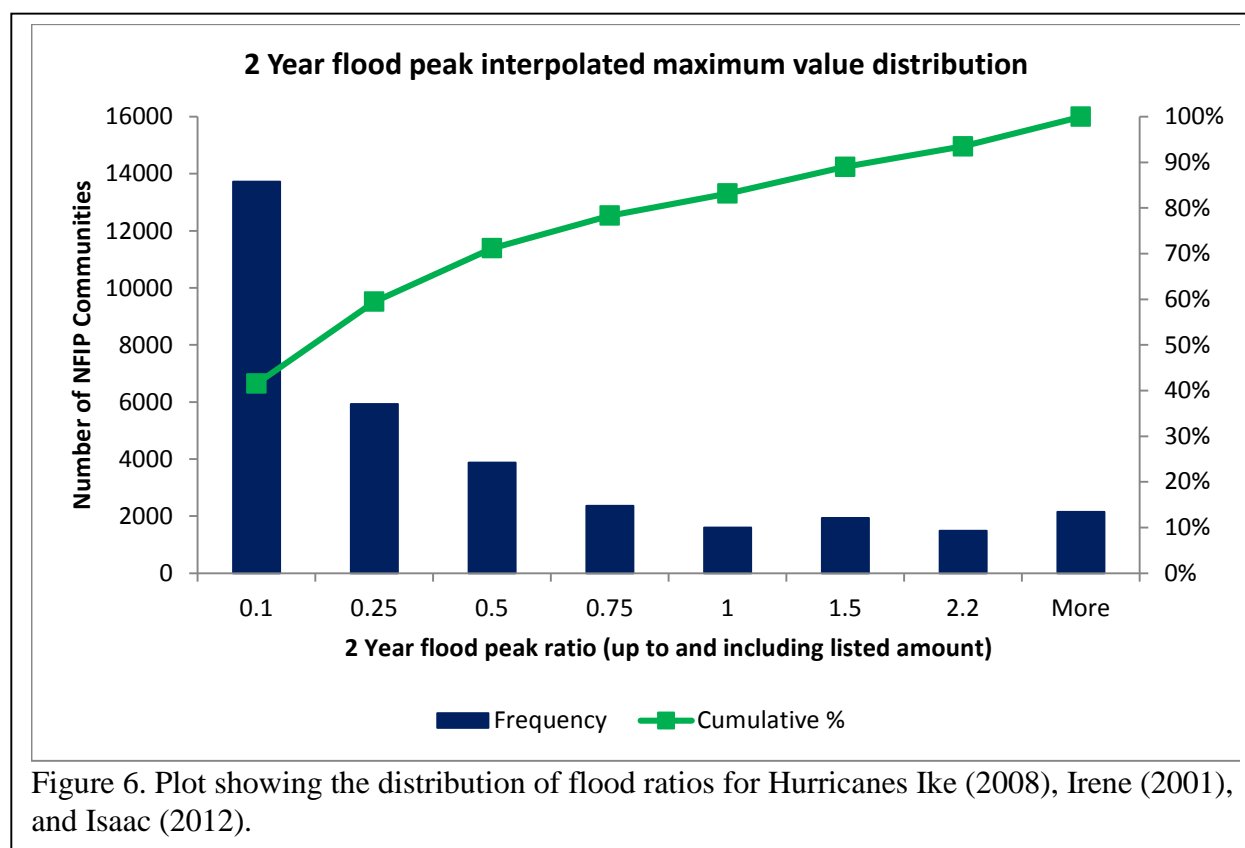
resulting from rising water is explicitly excluded in homeowners' insurance policies, but such coverage has been available since 1968 through the federally managed NFIP. Thus, the NFIP is the primary source of residential flood insurance. We benefit from a unique access to its entire policy portfolio from 2001 to 2012 as well as individual policy claim data.

In order for individual property owners to be able to purchase flood insurance from the NFIP, the community that the property owner resides in must be an NFIP participating community (FEMA 2005a, b). The NFIP specifically defines a “community” as a governmental body – including cities, towns, villages, townships, counties, parishes, special districts, states and Indian nations - with the statutory authority to enact and enforce development regulations. As we do not have access to individual claim and policy address data, claims will be aggregated to this NFIP community level, serving as our geographic unit of analysis in the loss modeling. Thus, we interpolate the individual stream gauge 2-year flood peaks to the community geospatial level where interpolation utilizes min/max neighbors 3/5; radius=1 meter to ensure the min/max neighbors are the parameters it uses to interpolate values. We have identified a total of 28,600 communities in the United States (note, not all 28,600 participate in the NFIP as we discuss below). Figure 5 shows the community-based interpolated stream gauge values for Hurricane Irene in 2011.



Similar interpolated 2-year flood peak hazard data have been produced for Ike 2008 and Isaac

2012. Across all three storms a total of 33,052 communities were impacted. The vast majority of these communities (83 percent) experienced flooding that would be considered action or bankfull, i.e., maximum interpolated 2-year flood peak ratio < 1.0. Nonetheless, 1483 communities experienced major flooding from one of these three storms (Figure 6).



For each of these three events, we determine the total number of residential flood claims incurred and the number of NFIP policies in-force in each of our 33,052 impacted communities. “Residential” equates to single-family, two to four family, and other residential structures. Non-residential (i.e., primarily commercial) structures covered by the NFIP, less than five percent of the total insured portfolio, are excluded from this analysis. Since we are focused on analyzing riverine flood losses, we exclude all claims explicitly due to “tidal water overflow” as classified by the NFIP (i.e., storm surge losses).

Again, we have identified a total of 28,600 communities in the United States, of which 22,016 participate in the NFIP program. Although 22,016 communities participate in the NFIP only 18,336 of them have any policies-in-force as of 2012. From our 33,052 impacted communities, 21,900 of them participate in the NFIP with at least 1 policy-in-force. As NFIP claims could have only been incurred in a participating community with policies-in-force, we restrict our regression analysis to these 21,900 communities. Across all three storms a total of 100,482 inland flood claims were incurred in all impacted communities. However, residential claims (i.e., all residential) were incurred in only 2,524 of the 21,900 impacted NFIP participating communities. Thus, 88 percent of impacted NFIP communities incurred no NFIP flood claims, or a relatively high number of 0 claim observations.

As the dependent variable in our multivariate analysis is the number of NFIP flood insurance claims occurring in an impacted census tract, which is a non-negative count (including zero value observations), we specifically utilize a zero-inflated negative binomial (ZINB) count model estimation. A ZINB specification allows for over-dispersion resulting from an excessive number of zeroes by splitting the estimation process in two: 1) estimating a probit model to predict the probability that zero claims take place in a given tract (i.e., the inflation portion of model); and 2) estimating a negative binomial (NB) model to predict the count of claims in a given tract.

In addition to the maximum 2-year flood peak values in each community represented by the NWS classification (bankfull is the omitted category), we also control for other relevant exposure factors including the number of housing units (2010 census data) and the number of flood insurance policies-in-force in each community (from 2012 policy portfolio). For statistical power purposes we pool the data from all three storms; although all tropical cyclones these are different storms we thus control for any unobserved event-specific fixed effects through event dummy variables (one for each storm); with Ike 2008 being the omitted category. Lastly, we have defined

for each NFIP community the percentage of the community at high flood risk as designated by a 1996 Natural Disaster Study conducted by the Federal Emergency Management Agency on behalf of the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (<https://www.npms.phmsa.dot.gov/DisasterData.aspx>). This is a very high resolution data (1km grid) that uses underlying topography and hydrography of the area while estimating the rankings of flood risk on a 0-100 scale that represent relative risk of flood hazard. In the dataset, a scale of 0-69 is indicative of a low risk area, 70-84 is indicative of a medium risk area and 85-100 is indicative a high risk area. For each community we calculated the proportion of area representing these three areas.

The initial regression results below illustrate the impact that higher 2-year flood peaks have in terms of claims incurred. In comparison to the omitted bankfull category, the modeled number flood claims all increase in direction and magnitude given minor, moderate, and major flood peak values experienced. Importantly, these flood peak hazard variables are all statistically significant at the 1 percent level. Other explanatory variable results are as expected as well. Similar statistical models will be run once the data is captured for all storms in our catalog. Further, the modeling will be refined and enhanced as continue to move forward with the analysis.

Table 1. Statistical modeling of the number of inland flood insurance claims using a zero-inflated negative binomial model. The predictors are the flood ratios (transformed into a dummy variable, with bins of (0; 1], (1; 1.5], 1.5; 2.2], and (>2.2), where (0; 1] is the omitted dummy variable) category; the number of flood insurance policies-in-force in each community (from 2012 policy portfolio); the number of housing units (2010 census data). Each storm is modeled as a dummy variable with respect to Hurricane Ike (2008). The percentage of the NFIP community at different flood risk level (low, medium, and high) is also used as predictor. The probit model is also shown, together with the inflation factor α (when $\alpha = 0$ the NB simply reduces to the Poisson model).

Zero-inflated negative binomial regression	Number of obs	=	21900
	Nonzero obs	=	2524
	Zero obs	=	19376
Inflation model = probit	LR chi2(10)	=	1068.17
Log likelihood = -12836.71	Prob > chi2	=	0.0000

claims_allres	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
claims_allres						
minor	.9320031	.1270665	7.33	0.000	.6829573	1.181049
moderate	1.216107	.1190518	10.21	0.000	.9827694	1.449444
major	2.106479	.0952806	22.11	0.000	1.919733	2.293226
respolicies_2012	.0002064	.0000156	13.21	0.000	.0001757	.000237
housing_2010	-7.60e-07	6.55e-07	-1.16	0.246	-2.04e-06	5.25e-07
irene2011	-.3581048	.0891554	-4.02	0.000	-.5328462	-.1833635
isaac2012	-1.20694	.1284283	-9.40	0.000	-1.458655	-.9552255
prop_lowrisk	1.159452	.666244	1.74	0.082	-.1463623	2.465266
prop_medrisk	1.853136	.6775227	2.74	0.006	.5252156	3.181056
prop_highrisk	2.807209	.6727361	4.17	0.000	1.488671	4.125748
_cons	-.4980337	.6692285	-0.74	0.457	-1.809697	.8136301
inflate						
max	-1.622697	.0580399	-27.96	0.000	-1.736453	-1.508941
respolicies_2012	-.0051107	.0004015	-12.73	0.000	-.0058976	-.0043238
_cons	2.555071	.0527685	48.42	0.000	2.451647	2.658496
/lnalpha	1.738802	.0291973	59.55	0.000	1.681576	1.796028
alpha	5.690522	.1661478			5.374021	6.025664

It is clear that we are well on schedule with what proposed for Year 1 and moving into the analyses proposed for Year 2.

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Student support

- Jeffrey Czajkowski (Post-doc)
- Marilyn Montgomery (Post-doc)

Outcomes since the beginning of the project**Presentations:**

- North American Willis Research Network Meeting, New York City, April 2015

Information Transfer Program Introduction

Information transfer continues to remain an integral and successful component of the Iowa Water Center's operations. Infoshare takes place through the IWC website, social media, (including Facebook, Twitter, an e-newsletter, and new in FY2014: a blog) as well as attendance at and promotion of conferences, symposiums, field days, public meetings and other professional events. These efforts simultaneously benefited attendees of the events and the Center by raising public profile of the Center, its efforts, and the Water Resources Research Institutions as a whole.

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2014IA254B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	IA-004
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Richard Cruse, Melissa S Miller

Publication

1. Miller, A., K. Lamkey, S. Mickelson, J. Enos-Berlage, I. Rodrigues de Assis, R. Braganca Alves Fernandes, S. Fales, C. Lindahl, C. Filstrup, A. Heathcote, J. Downing, K. Gesch, B. Hornbuckle, M. Adkins, T. Isenhardt, R. Cruse, A. Kaleita, H. Kohler, J. Laflen, K. Moore, R. Hintz, S. Flynn, N. Bowden, J. Singer, K. Kohler, D. Wiggans, J. Pesek, M. Tiedeman, L. Burras. Getting Into Soil and Water: 2014. Iowa Water Center, Ames, IA.

2014-2015 Iowa Water Center Information Transfer Project

The Iowa Water Center (IWC) places great importance on the Information Transfer aspect of its 104(b) program. Information Transfer activities achieve multiple goals for IWC: inform consumers about water related issues and research; connect researchers to complementing projects and facilitate collaboration; publicize IWC and its programs and products; and publicize and promote the Water Resources Research Institute Program and U.S. Geological Survey. IWC staff spends a significant portion of their time devoted to organizing, supporting and attending multiple education and outreach activities throughout the year. In addition to events, IWC staff prioritizes maintaining an effective web and social media presence.

Iowa Water Conference

The predominant Iowa Water Center information transfer product is the Iowa Water Conference, which was held March 3-4, 2014. The 2014 event was the 8th annual occurrence and had a theme of "Making Connections, Solving Problems: Water strategies for success in a changing world." Attendance increased over the 2013 conference with an additional 45 paid registrations (251 v. 296) and approximately 350 attendees total. In addition, entries in the poster contest as well as non-profit displays increased by 30% each and commercial exhibits doubled over 2013. The highlight of the 2014 conference was an optional workshop and conference breakout presentation on stream stabilization, made by Dave Derrick, Potomologist and Vice President, River Research and Design, Inc.

Getting Into Soil and Water

The 2014 edition of the publication *Getting Into Soil and Water*, produced with the Soil and Water Conservation Club at Iowa State University, was released at the Iowa Water Conference in 2014. This 44 page publication contains articles from 30 authors, including IWC Advisory Board members Tom Isenhardt and Marty Adkins and current IWC 104(b) seed grantee Brian Hornbuckle. It is available for download from <http://www.water.iastate.edu/content/getting-soil-water>. The 2014 publication was distributed to approximately 2000 individuals, including Iowa Water Conference attendees, high school science and vocational agriculture teachers, attendees to the 2014 Iowa Environmental Council annual conference, potential students to the Agronomy program at Iowa State University, and handed out at various conferences where IWC was an exhibitor.

Speaking engagements

Iowa Water Center Director Rick Cruse was invited to give several presentations during this reporting period, including:

Changing and Adopting: Agriculture and the Countryside. Presented at 14th International Scientific Days, Karoly Robert College. Gyongyos, Hungary. March 27, 2014.

Soil Erosion: How much is really happening. Iowa Learning Farm Webinar Series. April 16, 2014.

Available at:

<https://connect.extension.iastate.edu/p7sqo5f1v71/?launcher=false&fcsContent=true&pbMode=normal>

!

Food Security and Climate Change. Perry High School Career Day. Perry Iowa. April 24, 2014

Our degrading soil resource. Presented at: Adult Forum at Collegiate Presbyterian Church. Ames, Iowa. May 11, 2014.

Soil and Water Resource: Challenges and opportunities for biofuels. Presented at: 3rd European Biorefinery Training School. Budapest, HUNGARY. July 8, 2014.

Resource Degradation, Climate Change and Rising Global Demand. Presented at: Research School for Socioeconomic and Natural Sciences of the Environment. Bonn, Germany. July 15, 2015.

Soil erosion: how much is really occurring. Presented at Opening of Warren County Fair. Indianola, IA. July 21, 2014.

Economics of soil erosion. Presented at the State Chapter of the Soil and Water Conservation Society Annual Meeting. Nevada, IA. September 26, 2014.

Iowa Daily Erosion Project. Presented as North Central Region Water Network Extension Beyond Borders Conference. Bloomington, MN. October 1, 2014.

Invest in Clean Water – Values and Resources. Presented at Iowa Environmental Council Annual Meeting. Des Moines, IA. October 10, 2014.

Transforming Midwestern Agriculture with Continuous Living Cover: Challenges and Opportunities for Biofuels. Presented at the Green Lands, Blue Waters annual conference. Decatur, Illinois. November 19, 2014.

The Economics of Soil Health: What is erosion costing us? Presented at the Southwest Agricultural Conference. Ridgeway, Ontario. January 6 & 7, 2015. (Snow storm canceled flights – presented as webinar).

Soil Erosion; How much is really occurring and why is it important. Presented at the Iowa Conservation Education Coalition Diving into Networking Winter Workshop. Guthrie Center, Iowa. February 6, 2015.

Conference planning, exhibiting, and attendance

The Iowa Water Center and its staff assisted in planning and/or exhibiting at various events during the reporting year. At each event, staff identified themselves as Water Center representatives and shared information about IWC and its products. These events include:

-Global Food Security Consortium (attendee); April 29-30, 2014; Ames, IA.

-Iowa Children's Water Festival (with Iowa Learning Farms as workshop leader); May 15, 2014; Ankeny, IA.

-Conservation Districts of Iowa Annual Conference (exhibitor); September 3-4, 2014; West Des Moines, IA.

-North Central Region Water Network conference (attendee); September 29-Oct 2, 2014; Minneapolis, MN.

-Iowa Environmental Council Annual Conference: ENGAGE IN YOUR FUTURE: Creating a healthier, sustainable tomorrow (exhibitor); October 9, 2014; Des Moines, IA.

-Practical Farmers of Iowa Annual Conference: Mapping Our Future (exhibitor); January 23-24, 2015; Ames, IA.

IWC staff also attended various meetings throughout the year, including those of watershed organizations and for research projects.

Web presence

The Iowa Water Center recognizes the importance of an effective web presence. To that end, IWC maintained an engaging website, bi-monthly electronic newsletters, and social media accounts on Twitter and Facebook.

Website: During the reporting period, IWC had 3,696 unique visitors to the website (water.iastate.edu), an increase of over 9% from 2013-2014. The average session duration was 2:32 with an average 2.66 pages viewed per session.

Newsletter: Newsletters were released the 2nd and 4th Thursday of each month during the reporting period for a total of 22 newsletters. At the beginning of the reporting period, the newsletter had 91 subscribers with a 54% open rate and 16% click-through rate. The last newsletter in the reporting period had 128 subscribers with a 53% open rate and a 30% click-through rate.

Twitter: At the end of the reporting period, IWC's Twitter account had 365 followers, gaining 184 followers throughout the year – an increase of over 50%.

Facebook: IWC started the reporting period with 62 likes on Facebook and gained 104 likes during the year, ending at 166. The IWC Facebook page garners the most interaction leading up to and following the Iowa Water Conference.

In the academic summer period, IWC staff hired and supervised a graduate student to operate IWC's web presence. The student was studying agronomy, but had interest in scientific communication. The student spent ten hours per week learning the different platforms of social media and website management and developed skills in identifying and developing unbiased materials of interest to IWC consumers.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	3	0	0	0	3
Masters	1	1	0	0	2
Ph.D.	2	1	0	0	3
Post-Doc.	0	2	0	0	2
Total	6	4	0	0	10

Notable Awards and Achievements

As president-elect of NIWR, Dr. Cruse and IWC staff successfully planned and hosted the annual director's meeting in Washington, DC from Feb 8-11, 2015.

The Soil and Water Conservation Club at Iowa State University, advised by Dr. Cruse, was honored with the Merit Award by the Soil and Water Conservations society in July 2014 for the publication Getting Into Soil and Water, which is supported by base funding. The Merit Award is given in recognition of an outstanding activity, product, or service by a group, business firm, corporation, or organization that promotes the conservation of soil, water, and related natural resources.